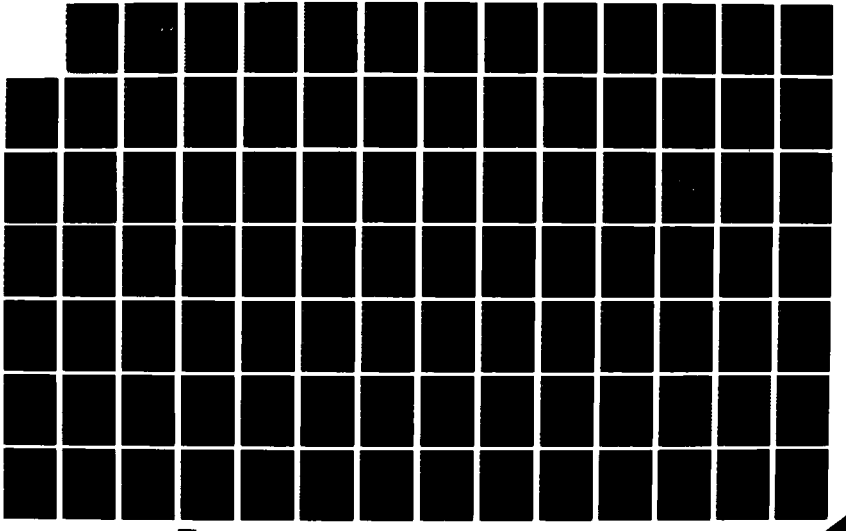
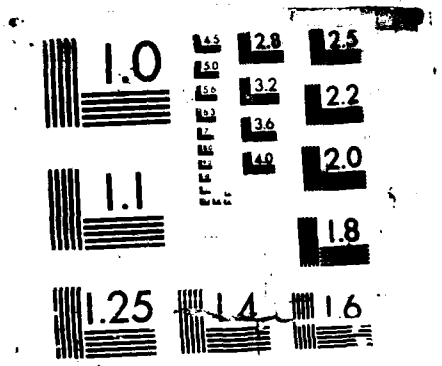
AD-A183 985 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND PARTIAL PHASE 2 VOLUM (U) FMC COR MINNEAPOLIS MINN NORTHERN ORDNANCE DIV R RATHE ET AL APR 87 1/3

UNCLASSIFIED FMC-E-3041-VOL-C-PT-1 DAAA21-86-C-0047 F/G 19/6 NL





MICROCOPY RESOLUTION TEST CHART

DTIC FILE COPY

Lightweight Towed Howitzer Demonstrator

Final Report

Volume C - Part 1

Dynamic Analysis Report

DTIC
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SEP 0 3 1987
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C&D

AD-A183 985

April 1987

Contract Number DAAA21-86-C-0047

FMC CORPORATION
Northern Ordnance Division
4800 East River Road
Minneapolis, Minnesota 55421

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A183 985 / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Final report for the Lightweight Towed Howitzer Demonstrator	5. TYPE OF REPORT & PERIOD COVERED Final: 20 December 1985 - 13 March 1987
	6. PERFORMING ORG. REPORT NUMBER E-3041
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9. PERFORMING ORGANIZATION NAME AND ADDRESS FMC CORPORATION, Northern Ordnance Division 4800 East River Road Minneapolis MN 55421	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Item 0001 LTHD Phase I and Partial Phase II
11. CONTROLLING OFFICE NAME AND ADDRESS AMCCOM AMSMC-PCW-A(D) Dover NJ 07801-5001	12. REPORT DATE April 1987 13. NUMBER OF PAGES 4,856
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) AMCCOM AMSMC-FSA-F Dover NJ 07801-5001	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

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18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) 155mm towed gun howitzer, advanced weapons, composite cradle, composite hydraulic actuators, composite trails, field artillery weapon, firing stability analysis, howitzers, hydraulic control valves with force feedback, hydraulic joystick control of gun direction, hydraulic inertial rammer, hydraulic opening breech, hydraulic primer autoloader, ~~lightweight towed howitzer demonstrator (LTHD)~~, load out of battery howitzer, mortar howitzer, recoil energy recovery, recoil mechanism, ~~using~~ metal matrix composites, titanium muzzle brake, titanium platform, titanium spade, titanium walking beams, thermal stability, towing stability analysis, unconventional weapons, ~~and weight reduction of artillery~~

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The LTHD (Lightweight Towed Howitzer Demonstrator) was to be a 9,000 lb equivalent to the M198, transportable via Blackhawk helicopter, with reduced emplacement time using fewer personnel. The FMC design achieved weight reduction via a mortar-like configuration, composites structure, and hydraulic actuators. Recovery of power from the recoil system, in turn, facilitated crew reduction via hydraulic emplacement, four-way joystick tube lay, and power ramming. FMC completed Concept Development (Ph I) and two-thirds of Detailed Design (Ph II) prior to funds running out.

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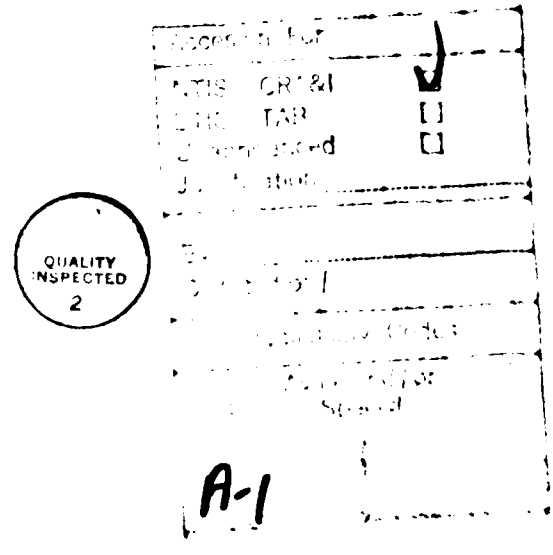

DESCRIPTION: MASS-COORDINATE DATA FILE

STATUS:

All component weights were recorded on the parts list (TDP, Dwg. 12585710-125) as they became known. This data, along with CAD-calculated values of individual component center of gravities, was entered into data files compatible with a CG and inertia-calculating computer program on the VAX called GRAVITY.BAS.

To simplify the stability analysis, component inertias about their own centers of gravity was neglected. The stability program (HOP.BAS) which reads in this data does, however, calculate the system inertia from the pivot point for hop. A better approximation of the tube inertia is used in this calculation. It has been estimated when the values for component inertias are ignored the resulting system inertia value is approximately 10 percent low.

The coordinate system used in all calculations is defined as follows:

Origin - defined as the intersection of the barrel center line with the trunnion center at the trunnion height (18.25 inches off ground).

X - the line in the horizontal plane perpendicular to the barrel centerline, with the positive direction to the left of barrel centerline.

Y - the line in the vertical plane perpendicular to the barrel centerline, with up being the positive direction.

Z - same as the barrel centerline, with the positive direction towards the muzzle.

The three data files containing the weight and CG data are described as follows:

LFBR.DAT (LTHD, Fire position of system, Battery position of barrel, Recoil components only). This separate data file is created so that the stability program (HOP.BAS) which uses this data can "move" these components separately during the simulation.

LFTE.DAT (LTHD, Fire position of system, Tow position of components, (non-recoiling) Elevating and traversing components only). (By definition, these components only rotate and do not translate.) This data file allows HOP.BAS to elevate and traverse only these components and the recoiling components.

LFTS.DAT (LTHD, Fire position of system, Tow position of components (except trails), Stationary components only). These

are all components that are not contained in the above two data files. They never translate and rotate only if hop occurs.

The reader is referred to the parts list for individual component weights or the following pages of this section for listings of the above data files which contain both weight and C.G. data.

AUTHOR: Scott Dacko

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File _HSC000$DUA9:[M20.DACKO_SG.VMS.WEIGHT]LFBR.PRT;2 (1422,51,2), last revised
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GGGGGGGGGG    Digital Equipment Corporation - VAX/VMS Version V4.4     GGGGGGGGGG
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LFBR

TOTAL WEIGHT = 3870.15 ← FINAL RECOIL WEIGHT

C.G. X COORD (IN) = -.274826

C.G. Y COORD (IN) = -.119819

C.G. Z COORD (IN) = 199.476

JYZ (FT-LB-S^2) = 35568.8

JXY (FT-LB-S^2) = 3.24387

JXZ (FT-LB-S^2) = 35571

DESCRIPTION	WEIGHT	X	Y	Z
5725	5	-13.5	10.88	118
5726	1	-11.5	1.25	105.48
5727	1	-4.25	2.5	105.48
5728	8.76	5	8.75	216.27
5766	181	0	-1.8	366.7
5781.01	26.8	0	0	128.747
5781.02	16.82	0	0	164.747
5781.03	19.44	0	0	200.057
5781.04	22.77	0	0	237.747
5781.05	27.66	0	0	340.997
5782	12.33	0	0	214.45
5786	1	0	4.03	349.8
5787	24	0	0	347.8
5788	24.67	0	0	189.01
5789	495	-2	0	113.2
5802	45	-2	-1	105
5816	92.15	0	0	188.13
5947	91.22	0	0	178.125
5948	91.5	0	0	178.125
5954	3.652	0	0	120.623
5955	5.842	0	0	118.807
5963	86.43	7.38	-2.72	234.577
5964	79.11	-7.38	0	234.577
5965	.17	3.62	6.28	120.371
5966	.33	3.62	6.28	120.8
5967	1.06	0	0	121.25
5968	4.78	0	0	214.45
5969	7.4	0	0	214.43
6002.01	.05	0	4	349
6002.02	6.36	0	0	214.457
6002.02	6.25	0	0	214.457
6002.03	.6	0	0	121.25
6033	1	0	0	207.13
9999	2480	0	0	203.857

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           LL            FFFFFFFF       TT         EEEEEEEE
           LL            FFFFFFFF       TT         EEEEEEEE
           LL            FF             TT         EE
           LL            FF             TT         EE
           LL            FF             TT         EE
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           LLLLLLLLLL    FF             TT         EEEEEEEEEE
           LLLLLLLLLL    FF             TT         EEEEEEEEEE

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HHHHHHHHHH    Digital Equipment Corporation - VAX/VMS Version V4.4      HHHHHHHHHH
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```

LFTE
TOTAL WEIGHT = 2478.3
C.G. X COORD (IN) = .526638
C.G. Y COORD (IN) = 2.89592
C.G. Z COORD (IN) = 161.457
JYZ (FT-LB-S^2) = 155 3.8
JXY (FT-LB-S^2) = 51.5709
JXZ (FT-LB-S^2) = 15485.9

DESCRIPTION	WEIGHT	X	Y	Z
5712	135	0	-.72	199.08
5713	135	0	-.72	199.08
5716	44	0	29.87	34.13
5718	130	12.5	1.75	181.5
5719	130	-12.5	1.75	181.5
5720	166	2.5	21.75	179
5728	10.5	5	8.75	169
5729	59.5	0	10.5	135.66
5760	2.5	0	-8.5	242.25
5761	1	0	-8.5	242.25
5763	20.13	0	-8.5	242.25
5764	20	0	-8.5	242.25
5771	.37	0	-15.875	173.75
5772	3.42	0	-14.5	150.55
5774	.63	0	-14.5	173.75
5775	.16	0	-14.25	173.75
5776	2.7	0	-14.5	173.75
5777	2.78	0	-14.5	171.58
5779	1.8	0	-8.5	242.25
5780	22.75	0	-13.46	158.83
5790	5.68	0	-16.31	173.75
5831	414	0	.526	93.518
5863	2.2	0	1.031	35
5864	3.34	0	1.031	35
5865	2.5	0	1.031	35
5892	2	16.5	14.25	240
5893	2	16.5	7.25	240
5894.01	1	19	14.25	236
5894.02	2	-16.5	14.25	240
5895	2	-16.5	7.25	240
5896	2	0	0	236
5900	15	14.25	0	28
5902	7	5.81	10.625	130
5912	19.2	-.22	0	127
5913	2.5	6.062	6.25	127
5914	2	13.875	9.375	127
5915	2.5	0	0	236
5916	2.5	6.5	-8	127
5917	1.5	7.25	5.125	127
5918	1.5	7.25	5.125	127
5921	1	0	0	236
5922	12	5.84	-2.015	236
5923	2	0	0	127
5925	18	0	12.75	65
5943	220	0	1.528	127
5944	250	0	0	236
5945	85.62	0	0	182
5949	14.6	0	0	182
5950	21.8	0	0	182
5951	4.95	0	0	235
5952	5.16	0	0	124.15
5959	1.04	0	-12	127

5960	2.07	0	1.625	127
5961	3.45	0	1.625	127
5971	2	0	0	236
5973	.106	0	2.75	123.875
5975	85.46	0	0	182
5976	2	0	0	236
5977	2	0	0	236
5978	2	7	11.44	127
5979	2	7	11.44	127
5980	2	-10	10.56	127
6002.68	1	0	16	236
6002.69	1	0	0	239
6002.7	1.26	0	-11.75	232.5
6002.71	.25	0	-10.25	233.88
6002.72	1.39	0	-10.25	235.12
6002.74	.11	0	17.12	232.5
6002.75	.19	0	16.5	235
6002.76	.11	0	14.5	234
6002.77	.04	0	15.12	232.5
6002.78	5.8	0	-8.5	241.5
6002.79	.27	0	16.4	102
6002.8	.28	0	-10.75	127
6002.81	.14	0	15.5	127
6002.82	.28	14.25	0	28
6002.83	.2	0	-14	14.47
6002.84	.46	0	1.031	35
6002.85	.36	0	1.031	35
6002.86	.18	0	-14.5	150.8
6002.87	.68	0	-14.5	170.75
6002.88	.1	0	-15	173.75
6002.89	.07	0	-15	173.75
6002.9	.19	0	-15	172.75
6002.9	.19	0	-15	173.75
6003.45	.03	0	-11.94	232.5
6003.46	.03	0	15.18	232.5
6003.47	.25	0	-8.5	242.25
6003.48	.1	0	15.78	102
6003.49	.16	0	1.625	127
6003.5	.3	0	1.031	35
6003.51	.07	0	-4.125	140.75
6003.52	.11	0	-14.5	150.8
6003.53	.2	0	-14.5	170.75
6004.01	8	0	-8.5	242.25
6005.51	.07	0	-13.56	232.5
6005.52	.03	0	-10.25	238.5
6005.53	.08	0	-11.25	235.12
6005.54	.02	0	-12.12	232.5
6005.55	.05	0	17.38	232.5
6005.56	.03	0	16.25	235
6005.57	.03	0	15.25	232.5
6005.58	.04	0	15.93	102
6005.59	.04	0	1.625	127
6005.6	.04	14.25	0	28
6005.61	.04	0	-14	14.47
6005.62	.04	0	-4.125	140.75
6005.63	.12	0	-14.5	150.8
6005.64	.18	0	-14.5	170.75
6006.34	.27	0	-11.81	232.5
6006.35	.01	0	-2.75	149.25
6006.36	.8	0	-14.5	173.75
6006.37	.422	0	-14.5	173.75
6007.15	1.25	0	0	240

6007.15	.04	0	-2.75	149.75
6009.06	.08	0	-12.38	232.5
6009.07	.08	0	15.75	232.5
5009.08	.19	0	1.625	127
6010.11	.02	0	30.02	-44.75
6014.01	.01	0	-13	232.5
6026.03	.84	0	30.02	-44.75
7000	7.5	0	16	236
7001	5	0	0	240
7002	1.23	0	-13.25	232.5
7003	.88	0	-12.62	232.5
7004	.43	0	-12.18	232.5
7005	8.9	0	-10.62	234.25
7006	.77	0	16.5	232.5
7007	.7	0	-12	232.5
7008	.18	0	14.88	232.5
7009	.05	0	15.5	232.5
7010	.02	0	-12.12	232.5
7011	2.3	0	16.62	234
7012	1.41	0	15.88	232.5
7013	.73	0	15.44	232.5
7014	1.17	0	15.56	233
7015	32	0	24.23	60.54
7016	8.48	0	17.2	101
7017	1.19	0	15.375	127
7018	10	0	-14	14.47
7019	.25	0	-4.125	140.75
7020	.72	0	-4.16	157.18
7021	.12	0	0	166.2
7022	.41	0	-15.4	173.75
7023	.7	0	-14.5	174.5
7024	.8	0	-10.44	127
9994	25	15	8	127
9995	36.12	0	0	181.5
9997	170.4	0	0	181.5
9998	11.97	2.5	21.75	175
9999	.2	0	-8.5	245.56
9999	.13	0	1.031	35

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[M20,DACKO_SG], under account M22 at priority 100, started on printer
_VENUS$TXM6: on 8-APR-1987 14:08 from queue LNSYS.

IIIIIIIIII    3333333333333333333333333333333333333333333333333333    IIIIIIIIII
IIIIIIIIII    Digital Equipment Corporation - VAX/VMS Version V4.4    IIIIIIIIII
IIIIIIIIII    3333333333333333333333333333333333333333333333333333    IIIIIIIIII
```

8

LFTS
TOTAL WEIGHT = 2551.55
C.G. X COORD (IN) = 0
C.G. Y COORD (IN) = -3.58506
C.G. Z COORD (IN) = 26.9763
JYZ (FT-LB-S^2) = 784.343
JXY (FT-LB-S^2) = 13.6123
JXZ (FT-LB-S^2) = 770.731

DESCRIPTION	WEIGHT	X	Y	Z
9900	1325.72	0	-6.9	51.92
9901	1225.83	0	0	0

DESCRIPTION: COMPUTER FILE INVENTORY

STATUS: A complete listing of all computer programs and data files used in performing dynamic analysis is included in this section. Individual programs and files are described in the sections of this volume where appropriate.

Some files listed that are shown in S. Dacko's directory are old or not applicable to LTHD work and should be ignored.

AUTHOR: Scott Dacko, John Green, Jeff Ireland

TO: Scott DACKO

FROM: Jim DiHon

SYSTEM : VAX-8600 (VENUS)

VOLUME NAME : A026T1

SUBJECT: VOLUNTARY FILE ARCHIVING

Save set VAE870318.BCK created on 18-MAR-1987 13:40:09.13

[M20.DACKO_SG.VMS]120K.OUT;2
[M20.DACKO_SG.VMS]62500.OUT;3
[M20.DACKO_SG.VMS]62500C.OUT;2
[M20.DACKO_SG.VMS]70000.OUT;2
[M20.DACKO_SG.VMS]70K0.OUT;2
[M20.DACKO_SG.VMS]70K10.OUT;2
[M20.DACKO_SG.VMS]70K20.OUT;2
[M20.DACKO_SG.VMS]70K30.OUT;2
[M20.DACKO_SG.VMS]70K40.OUT;2
[M20.DACKO_SG.VMS]79000.OUT;3
[M20.DACKO_SG.VMS]79000C.OUT;2
[M20.DACKO_SG.VMS]90000.OUT;2
[M20.DACKO_SG.VMS]CURRENT.GRG;8
[M20.DACKO_SG.VMS]EHGD.GRG;1
[M20.DACKO_SG.VMS]EHSIX.GRS;2
[M20.DACKO_SG.VMS]ENERGY.EXE;45
[M20.DACKO_SG.VMS]ENERGY.FOR;60
[M20.DACKO_SG.VMS]ENERGY.OBJ;46
[M20.DACKO_SG.VMS]ENGHOURS.GRD;2
[M20.DACKO_SG.VMS]ENGHOURS.GRI;2
[M20.DACKO_SG.VMS]FC.GRD;4
[M20.DACKO_SG.VMS]FC.GRI;4
[M20.DACKO_SG.VMS]FCG.GRG;1
[M20.DACKO_SG.VMS]FCGS.GRS;1
[M20.DACKO_SG.VMS]GLOBAL.COM;27
[M20.DACKO_SG.VMS]GLOBAL.COM;26
[M20.DACKO_SG.VMS]HCP.BAS;12
[M20.DACKO_SG.VMS]HCP.EXE;7
[M20.DACKO_SG.VMS]HCP.OBJ;7
[M20.DACKO_SG.VMS]HCP3.BAT;2
[M20.DACKO_SG.VMS]HCP3.DAT;2
[M20.DACKO_SG.VMS]HCP3ACKUP.BAS;2
[M20.DACKO_SG.VMS]INTRO.TXT;4
[M20.DACKO_SG.VMS]LFTRORIG.DAT;1
[M20.DACKO_SG.VMS]LMRESET.DAT;1
[M20.DACKO_SG.VMS]LOADARM.EXE;1
[M20.DACKO_SG.VMS]MBT.EXE;5
[M20.DACKO_SG.VMS]MBT.FOR;6
[M20.DACKO_SG.VMS]MBT.OBJ;5
[M20.DACKO_SG.VMS]MCTION3M.DAT;3
[M20.DACKO_SG.VMS]MUZLBRKETEMP.EXE;4
[M20.DACKO_SG.VMS]MUZLBRKETEMP.FOR;6

DIRECTORY (8703/8)

```
[M20.DACKO_SG.VMS]MUZLBRKETEMP.LIS;4
[M20.DACKO_SG.VMS]MUZLBRKETEMP.MAP;3
[M20.DACKO_SG.VMS]MUZLBRKETEMP.OBJ;4
[M20.DACKO_SG.VMS]OUT.OUT;4
[M20.DACKO_SG.VMS]OUT.TJL;1
[M20.DACKO_SG.VMS]PROF.DAT;23
[M20.DACKO_SG.VMS]RECHOP.DAT;1
[M20.DACKO_SG.VMS]RECOIL.BAS;3
[M20.DACKO_SG.VMS]RECOIL.EXE;2
[M20.DACKO_SG.VMS]RECOIL.OBJ;2
[M20.DACKO_SG.VMS]RECPROF4.GRD;2
[M20.DACKO_SG.VMS]RECPROF4.GRI;2
[M20.DACKO_SG.VMS]RECPROFS.GRD;3
[M20.DACKO_SG.VMS]RECPROFS.GRI;3
[M20.DACKO_SG.VMS]RESET.LST;1
[M20.DACKO_SG.VMS]RPG.GRG;1
[M20.DACKO_SG.VMS]RPGS.GRS;1
[M20.DACKO_SG.VMS]SETHOST.LOG;3
[M20.DACKO_SG.VMS]TEMP1.OUT;1
[M20.DACKO_SG.VMS]TEMP2.OUT;1
[M20.DACKO_SG.VMS]TEMP3.OUT;1
[M20.DACKO_SG.VMS]WTDISTNW.BAS;1
[M20.DACKO_SG.VMS]WTDISTNW.EXE;1
[M20.DACKO_SG.VMS]WTDISTNW.OBJ;1
[M20.DACKO_SG.VMS]WTDISTW.BAS;2
[M20.DACKO_SG.VMS]WTDISTW.EXE;1
[M20.DACKO_SG.VMS]WTDISTW.OBJ;1
```

TO: JOHN GREEN

FROM: JIM DILLON

SYSTEM : VAX 8600 (VENUS)

VOLUME NAME : A026T1

SUBJECT: VOLUNTARY FILE ARCHIVING

Save set VAX870218.BCK created on 18-MAR-1987 13:30:33.24

[M90.GREEN_JE.VMS.LTHD]DYNFLOW.GRL;42
[M90.GREEN_JE.VMS.LTHD]DYNPRESS.GRL;42
[M90.GREEN_JE.VMS.LTHD]DYNTHETA.GRL;42
[M90.GREEN_JE.VMS.LTHD]ELEVATION.SAS;22
[M90.GREEN_JE.VMS.LTHD]ELEVATION.SAV;36
[M90.GREEN_JE.VMS.LTHD]GRAPH.SRG;154
[M90.GREEN_JE.VMS.LTHD]HELIUM.DAT;1
[M90.GREEN_JE.VMS.LTHD]NITROGEN.DAT;1
[M90.GREEN_JE.VMS.LTHD]NITROGEN.ENG;1
[M90.GREEN_JE.VMS.LTHD]RESET.PRT;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P01;2
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P02;2
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P03;2
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P04;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P05;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P06;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P07;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P08;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P09;1
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P10;2
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P11;3
[M90.GREEN_JE.VMS.LTHD]SIMULATION.P12;1
[M90.GREEN_JE.VMS.LTHD]STATIC.GRC;6
[M90.GREEN_JE.VMS.LTHD]STATIC.GRI;6
[M90.GREEN_JE.VMS.LTHD]STATIC.GRL;75
[M90.GREEN_JE.VMS.LTHD]STATIC.GRS;6

TO: Jeff IRELAND

FROM: Jim DILLON

SYSTEM : VAX 8600 (VENUS)

VOLUME NAME : A026T1

SUBJECT: VOLUNTARY FILE ARCHIVING

Save set VAR870318.BCK created on 18-MAR-1987 13:40:09.13

[M20.IRELAND_JV.VMS]ADDAT.FOR;3
[M20.IRELAND_JV.VMS]EN2.FOR;1
[M20.IRELAND_JV.VMS]ENERGY.FOR;1
[M20.IRELAND_JV.VMS]GLOBAL.COM;1
[M20.IRELAND_JV.VMS]HOP.BAT;1
[M20.IRELAND_JV.VMS]HOP.DAT;1
[M20.IRELAND_JV.VMS]OR2.FOR;34
[M20.IRELAND_JV.VMS]OR3.FOR;1
[M20.IRELAND_JV.VMS]ORIFI.FOR;5
[M20.IRELAND_JV.VMS]ORIFICE.FOR;1
[M20.IRELAND_JV.VMS]OUT.OUT;18
[M20.IRELAND_JV.VMS]RA2.FOR;1
[M20.IRELAND_JV.VMS]RAM.FOR;1
[M20.IRELAND_JV.VMS]TEST.FOR;3
[M20.IRELAND_JV.VMS]TE2.FOR;1
[M20.IRELAND_JV.VMS]TORQUE.FOR;7
[M20.IRELAND_JV.VMS]XAL.DAT;4

PART NUMBER: 12585725 C/100

DESCRIPTION: BREECH ACTUATOR

STATUS:

The breech actuation system consists of a hydraulic actuator, a mounting bracket, a modified breech crank, along with hoses, fittings and connectors. Layouts of this can be found in in the TDP, Cannon Assembly.

Breech actuator. A preliminary breech actuator drawing (TDP, Dwg. 12585725) showing all critical dimensions has been prepared by FMC and is to be finalized by York. Actuator size and pressure requirements have been determined based on torque data from Benet tests as well as FMC time cycle needs. Along with the actuator is a pilot-operated check to prevent accidental actuator retract (and breech closure) with hose failure. Also the actuator can only open the breech if the tube is in load position to prevent interference and damage with the cradle in other tube positions.

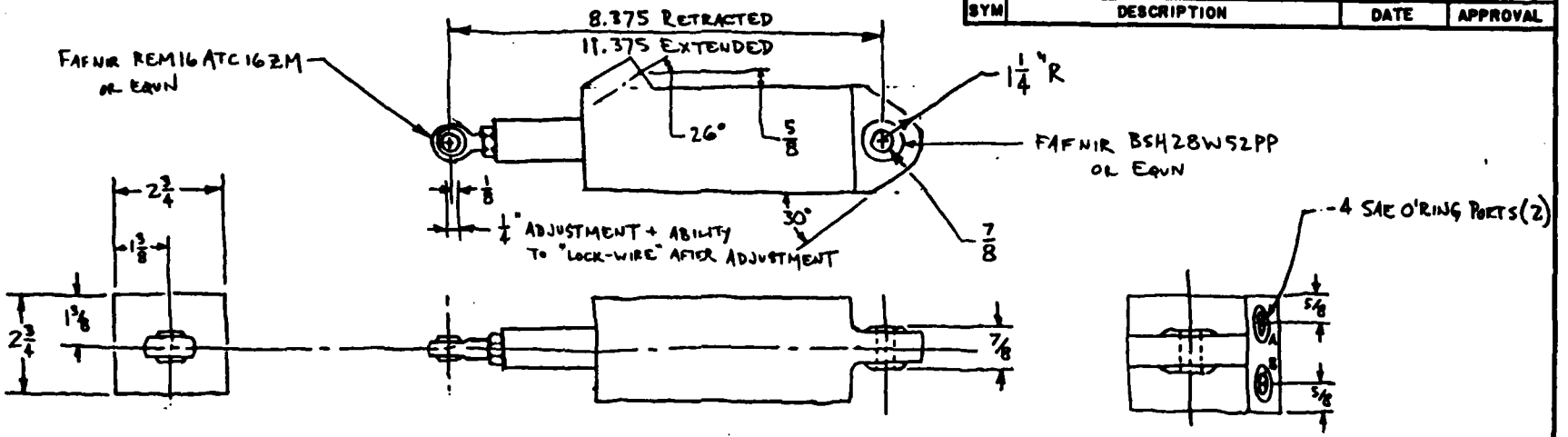
Breech crank. A modified Benet Crank drawing has been finalized by FMC and provided to Benet for manufacture. The non-functional Benet Crank ears are specified to be cut away to save weight.

Hoses, fittings and connectors. All hoses, fittings and connectors have been finalized and are specified on FMC technical data package gang-sheets. Layouts of these components can be found in the TDP, Cannon Assembly.

AUTHORS: Joe Turek, Jeff Ireland, Scott Dacko, Bart Anderson

DRAWING SIZE B

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL



B	A	POSITION
PRESSURE	RETURN	RETRACTED
RETURN	RETURN	EXTENDED ← NORMAL POSITION

OPEN
BREECH = .5 SEC

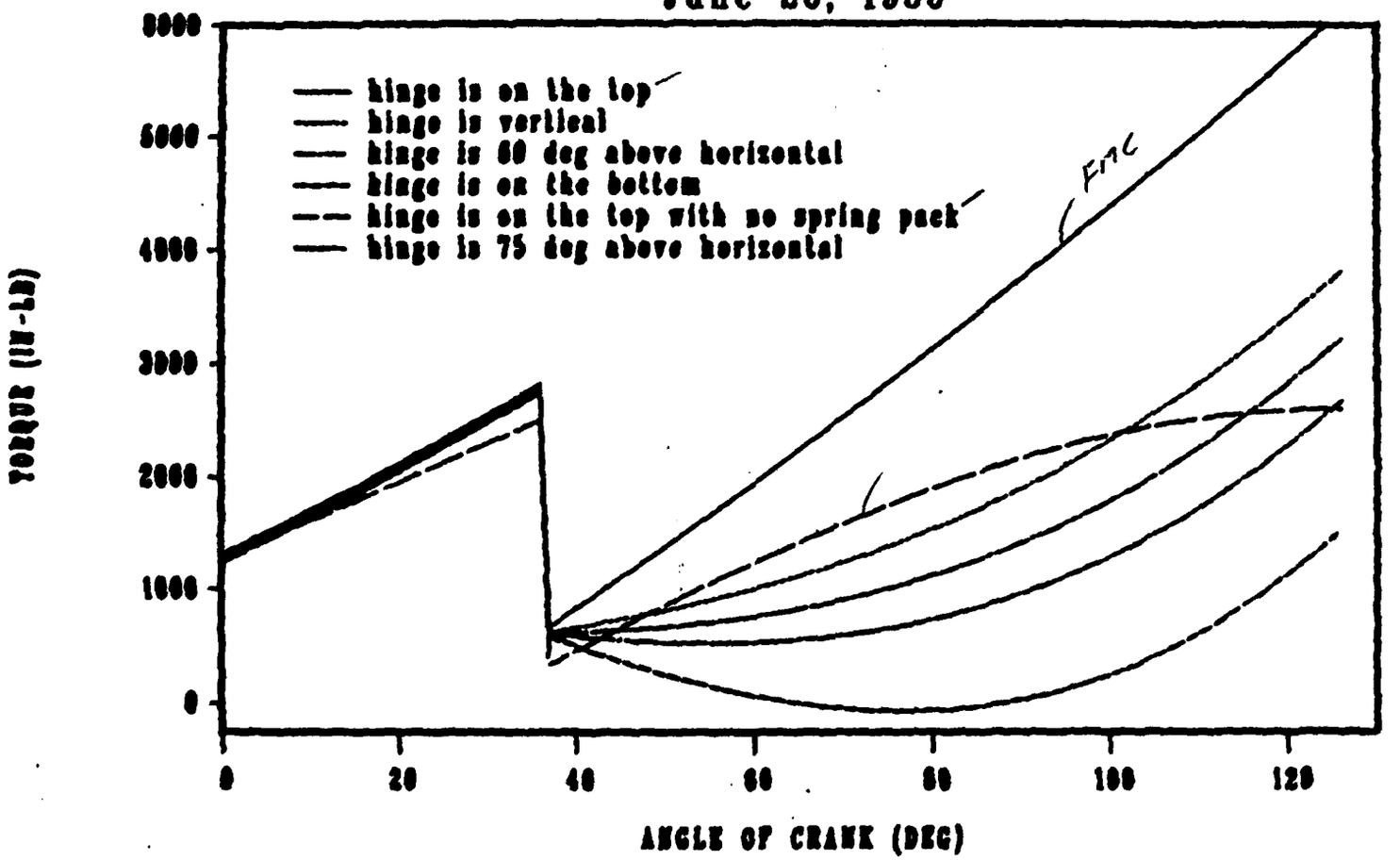
CLOSE
BREECH = .5 SEC

PART NO.

		MECHANICAL PROPERTIES	DO NOT SCALE DRAWING	ORIGINAL DATE OF DRAWING	U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER DOVER, NEW JERSEY 07801-5001
		YP	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	DRAFTSMAN / CHECKER	
		TS	TOLERANCES ON DECIMALS ±	ENGR / ENGR	BREECH ACTUATOR
		EL2	FRACTIONS ± ANGLES ±	ENGR / ENGR	
		RA	THIRD ANGLE PROJECTION		
		BH			SIZE B · FSCM NO. 19200 · T-1258 5725 /B
NEXT ASSY	USED ON	RH			SCALE · UNIT WT. · SHEET
APPLICATION					

SMCAR FORM 66, 1 JUN 86(TEMP) REPLACES ARRADCOM FORM 66, AUG 77, WHICH MAY BE USED UNTIL EXHAUSTED

TORQUE REQUIRED TO OPEN BREECH
June 26, 1986



Northern Ordnance Division
Minneapolis

BREECH MECHANISM OLD

DESCRIPTION	W (lbf)	r (IN)	Mr^2 (lbf-IN-SEC^2)	I_o (lbf-IN-SEC^2)
CARRIER	79.0	5.0	5.117	.512
BLOCK	107.0	10.0	27.720	2.772
GEAR SECTOR	6.0	10.0	1.554	.155
AUTO PRIMER	30.0	13.5	14.164	1.416
OBTURATOR PAD	26.0	10.0	6.736	.674
SPRING PACK	10.0	0.0	0.0	.135
PIVOT SHAFT	22.0	0.0	0.0	
			55.291	5.664

$I_{TOTAL} = (55.291 + 5.664)$ lbf-IN-SEC^2
$= 60.955$ lbf-IN-SEC^2

$T_{OPEN_{AVE}} \approx 2000.0$ lbf-IN

$\ddot{\theta} = A\cos(\omega t)$

$\dot{\theta} = (A/\omega)\sin(\omega t) + C_1^{\circ}$ $\quad t=0, \dot{\theta}=0, C_1=0$

$\theta = -(A/\omega^2)\cos(\omega t) + C_2$ $\quad t=0, \theta=0, C_2 = A\omega^2$

$\theta = (A/\omega^2)(1-\cos(\omega t))$

FORCE INPUT AT 1.0 IN RADIUS

$F_{IN} = (2000.0\ lbf\text{-}in + 2865.0\ lbf\text{-}in) / 1.0\ in$

$= 4865.0\ lbf$

$F_{PISTON} = 4865\ lbf\ (4.75 / 2.75) = 8403\ lbf$

$\pi/4\ (D_P^2 - (1.0\ in)^2)(2450\ lbf/in^2) = 8403.0\ lbf$

$D_P = 2.375\ in$

$D_R = 1.000\ in$

STROKE = 2.250 IN

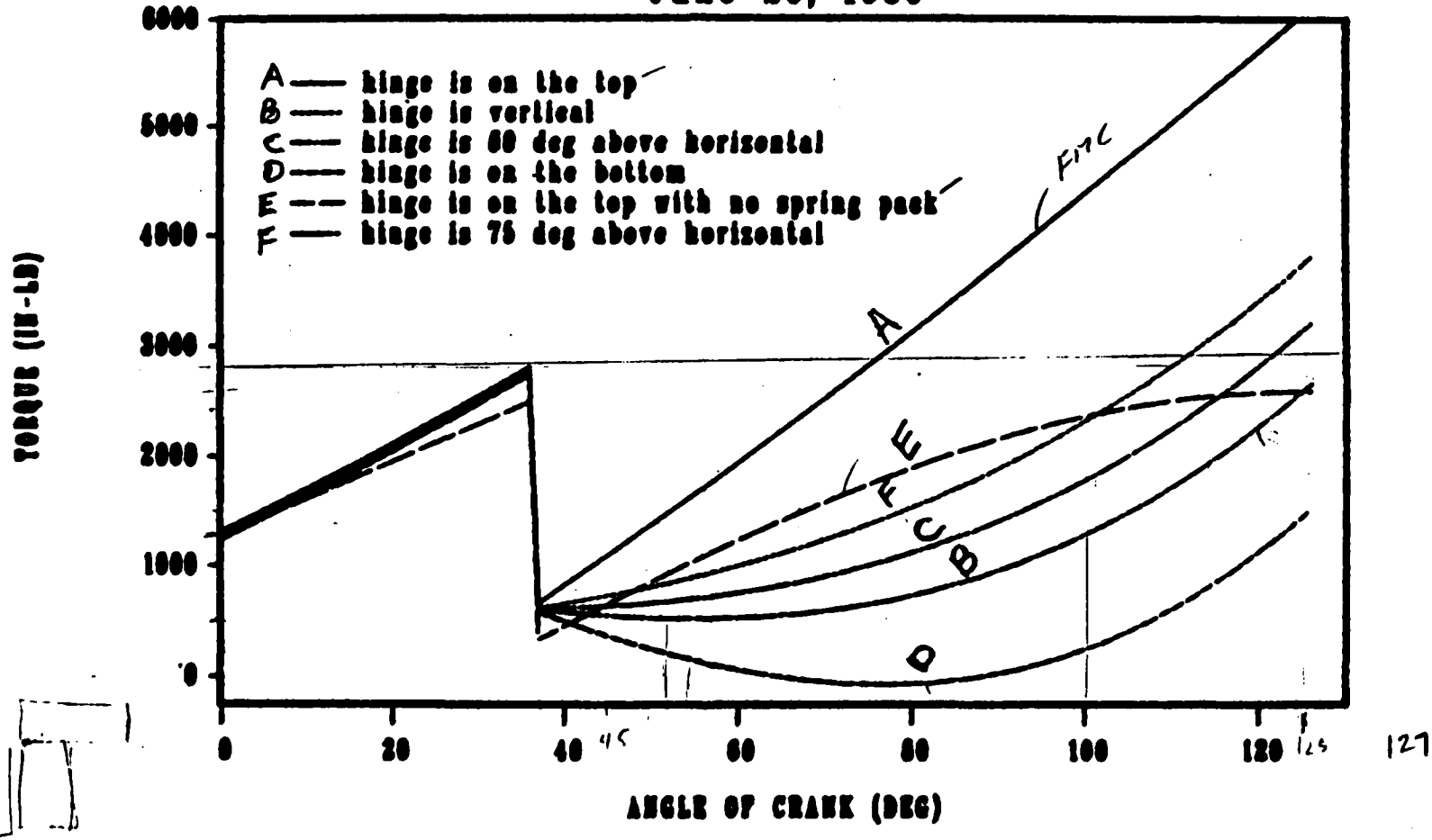
37° TO ROTATE BREECH 45°

90° TO SWING BREECH DOOR OPEN 90°

127°

BENET 8611

TORQUE REQUIRED TO OPEN BREECH
June 26, 1986



135

5

FMC Northern Ordnance Division Minneapolis

ACTUAL WEIGHT M185 BREECH 9/18/8

JEFF IRELAND
PAUL MELQUIST

BREECH BLOCK	107 LB	③
CARRIER (w/SPRINGS RACK)	79 LB	②
GEAR SECTOR	6 LB	①
M109 FIRING MECH CARRIER BLOCK	10 LB	③
OBTURATOR PAD (MUSHROOM w/NUT)	26 LB	③
SPRING PACK (w/ADJUSTOR)	10 LB	①
PIVOT SHAFT (CRANK)	22 LB	①

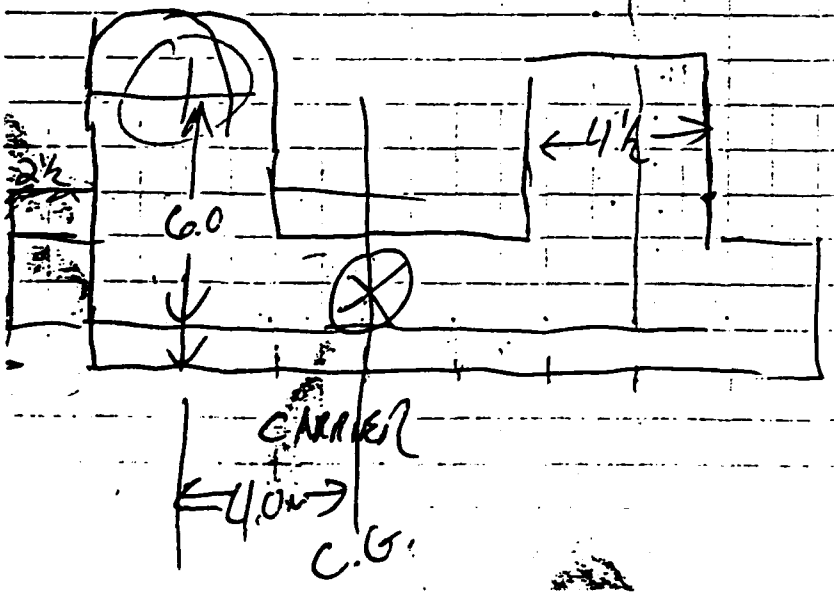
140

REPLACE WITH FIRING MECHANISM

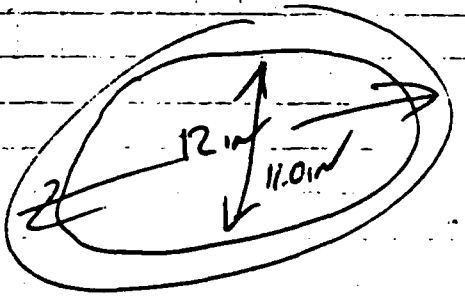
PIVOT SHAFT TO BREECH C/L 10.0 IN

PIVOT SHAFT DIA. O.D. 3 IN
I.D. 2 IN
LENGTH = 13.0 IN

6 IN THROW ON CRANK



BREECH



ROUGH SIZING

$\theta = 70° = 7\pi/18$ AT $t = .35$ SEC

$(A/\omega^2) = 7\pi/18$

$\omega t = \pi/2$

$\omega = 4.488$ RAD/SEC

$A = 24.608$ RAD/SEC^2

$\ddot{\theta}$ DECEL $\dot{\theta}_{MAX} = A/\omega = 5.483$ RAD/SEC $= 314.16°$/SEC

$20° = \frac{(314.16°)}{2} t$

$t = .127$ SEC

$\ddot{\theta}_{DECEL} = \frac{314.16°/SEC}{.127 SEC} = 2,473.7°/SEC^2 = 43.174$ RAD/SEC^2

$0 < \Delta < 37°$

TORQUE	Δ
1250 in-lbf	0°
2800 in-lbf	37°

$$T = \frac{(2800 - 1250)\text{in-lbf}}{37° - 0°}\,\Delta + 1250\ \text{in-lbf}$$

$$T = 41.891\left(\frac{\text{in-lbf}}{\text{DEG}}\right)\Delta + 1250\ \text{in-lbf}$$

$37° < \Delta < 127°$

TORQUE	Δ
500 in-lbf	55°
2750 in-lbf	127°

$$T = K(\Delta - 55°)^2 + C \qquad \Delta = 55° \quad C = 500\ \text{in-lbf}$$

$$\Delta = 127° \quad K = 1/2.304$$

$$T = [(\Delta - 55°)^2/2.304 + 500]\ \text{in-lbf}$$

ESMC Northern Engineering Division

ORIFICE'S IN BREECH CIRCUIT

9

1. CONTROL VALVE
2. LOAD POSITION VALVE
3. P.O. CHECK VALVE
4. INLET TO BREECH ACTUATOR
5. OUTLET OF BREECH ACTUATOR

$V_p = 3.053\ in/sec$

$A_p = \pi/4\left((2.75in)^2 - (1in)^2\right) = 5.154\ in^2$

$Q_p = 15.735\ in^3/sec$

PIPE LENGTH

1. 150 IN FROM BREECH ACTUATOR TO RESERVOIR

ASSUME 3/8 IN I.D.

2. 500 IN LENGTH TO BREECH ACTUATOR.

$V_{PIPE} = \frac{15.735 in^3/sec}{\pi/4(.375in)^2} = 142.468\ in/sec$

$Re = \frac{VD_H}{\nu} = \frac{142.468\ in/sec\ (.375in)}{.81\ in^2/sec} = 66.782$

$f = 64/Re = .958$

$\frac{\Delta P}{L} = \frac{f}{D_E}\left(\frac{\rho V^2}{2g}\right) = \left(\frac{.958}{.375in}\right)\frac{(.0308\ lbf/in^3)(142.468\ in/sec)^2}{2(386.087\ in/sec^2)} = 2.069\ PSI/in$

ASSUME 1/2 IN I.D.

$V_{PIPE} = \frac{15.735}{\pi/4(1/2)^2} = 80.138\ in/sec$

$Re = \frac{80.138(1/2)}{.8} = 50.086$

$f = 64/Re = 1.278$

$\frac{\Delta P}{L} = \left(\frac{1.278}{.5in}\right)\frac{(.0308)(80.138)^2}{2(386.087)} = .655\ PSI/in$

Northern Ordnance Division

BREECH MECHANISM

INERTIA WHILE BLOCK IS UNTHREADING

BREECH BLOCK	107.0 lbf	
GEAR SECTOR	6.0 lbf	Y = 6.0
OBTURATOR PAD	26.0 lbf	
	139.0 lbf	

$$I = \tfrac{1}{2} M r^2 = \tfrac{1}{2} (139 \text{ lbf} / 386 \text{ IN/SEC}^2)(6.0 \text{ IN})^2$$

$$I = 6.5 \text{ lbf-IN-SEC}^2$$

$I = 60.955 \text{ lbf-in-sec}^2$

$T_{OPEN} = 3000 \text{ lbf-in}$

$I\ddot{\theta} = F_p R_g - T_{OPEN}$

$$F_p = \left[P_a - \left(\frac{(A_p - A_R)\dot{X}}{115.5\, A_{OR}}\right)^2\right](A_p - A_R) - \left[P_R + \left(\frac{A_e \dot{X}}{115.5\, A_{OP}}\right)^2\right] A_p$$

$\ddot{\theta} = \ddot{X}/R_g$

STROKE $= \theta_{MAX} R_g = 127^\circ (\pi/180^\circ)(R_g)$ $\quad \theta_{MAX} = 127^\circ$

STROKE $= 2.217\, R_g$

$$\left(\frac{I\ddot{X}}{R_g} = \left[\left[P_a - \left(\frac{(A_e - A_R)\dot{X}}{115.5\, A_{OR}}\right)^2\right](A_p - A_R) - \left[P_R + \left(\frac{A_e \dot{X}}{115.5\, A_{OP}}\right)^2\right] A_p\right] R_g - T_{OPEN} \right.$$

$$\frac{I\ddot{X}}{R_g^2} = \left(P_a(A_p - A_e) - P_R A_p - \frac{T_{OPEN}}{R_g}\right) - \left(\frac{\dot{X}}{115.5}\right)^2 \left[\frac{(A_p - A_e)^3}{A_{OR}^2} + \frac{A_e^3}{A_{OP}^2}\right]$$

FOR ROUGH SIZING ASSUME $P_a = 2250$ PSI $\quad P_R = 500$ PSI $\quad \dot{X} = 0$

$$\frac{1}{2}\ddot{X} t^2 = 2.217\, R_g \qquad t = .5 \text{ sec}$$

$$\ddot{X} = 17.733 R_g$$

$$\frac{I(17.733\, R_g)}{R_g^2} = (P_a - P_R) A_p - P_a A_R - \frac{T_{OPEN}}{R_g}$$

$$\left(17.733 \frac{I}{R_g} + \frac{T_{OPEN}}{R_g} + P_a A_R\right) \Big/ (P_a - P_R) = A_p$$

$A_R = \pi(1.0)^2/4 = .7854 \text{ in}^2$
$R_g = 1.0 \text{ in}$
$A_p = 3.3417 \text{ in}^2$
$D_p = 2.063 \text{ in}$

USE $D_p = 2.125$ in

$\ddot{X} = A \cos \omega t$

$\dot{X} = \frac{A}{\omega} \sin \omega t + C_1$ $\quad t = 0, \dot{X} = 0, C_1 = 0$

$X = \frac{-A}{\omega^2} \cos \omega t + C_2$ $\quad t = 0, X = 0$

$0 = \frac{-A}{\omega^2} + C_2$

$C_2 = A/\omega^2$

$X = A/\omega^2 (1 - \cos \omega t)$

$\dot{X} = (A/\omega) \sin \omega t$

$\ddot{Y} = A \cos \omega t$

(

$t = 0, \dot{X} = 0, \ddot{X} = A$

$\ddot{Y} = [Pa(Ap - Ar) - Pr\,Ap - TOPEN/Rg]\, Rg^2/I$

$A = \ddot{X} = 32.339$ IN/SEC^2

$X = A/\omega^2 = 2.217\, Rg$

$\omega = [A/(2.217\, Rg)]^{1/2}$

$\omega = 3.819$

$Pa = 2250$ PSI
$Pr = 350$ PSI
$TOPEN = 3000$ lbf-in
$Rg = 1.0$ in
$I = 60.955$ lbf-in-sec^2
$Ap = 3.5465$ in^2
$Ar = .7854$ in^2

BREECH ACT.

PSI 4056 - 1252 = 2804

MIN SEAL FRIC AREA CYL

(3000 - 75)(2.125² - 1⁹ π/4) - (3000+15) 2.25² π/4

= 6804

TORQUE 500 IN LBS × 12 = 6000 IN LBS

F = 6000 / .75 = 8000 LBS OF FORCE

A = F / 3000 PSI = 2.667

A .875 ROD = 3.976

ROD .785

A 3.19

2⅛ DIA W/ 1 ROD = 2.76 - A

TO OPEN RETRACT

(3000 - 75)(2.125² - 1⁹ π/4) - (3000+15) 2.25² π/4 =

(2925)(3.5156 π/4) - (315)(4.5156 π/4)

4076 - 1117.16) = 6959

6959

OPEN TORQUE = 4523

.12

A = 2.25 = 3.976
A = 1 = .785

3.19 × 3000 psi = 9,570

7,970 ÷ 3000 = 2.66

A = 2.667 = 8000 = @ 3000 psi

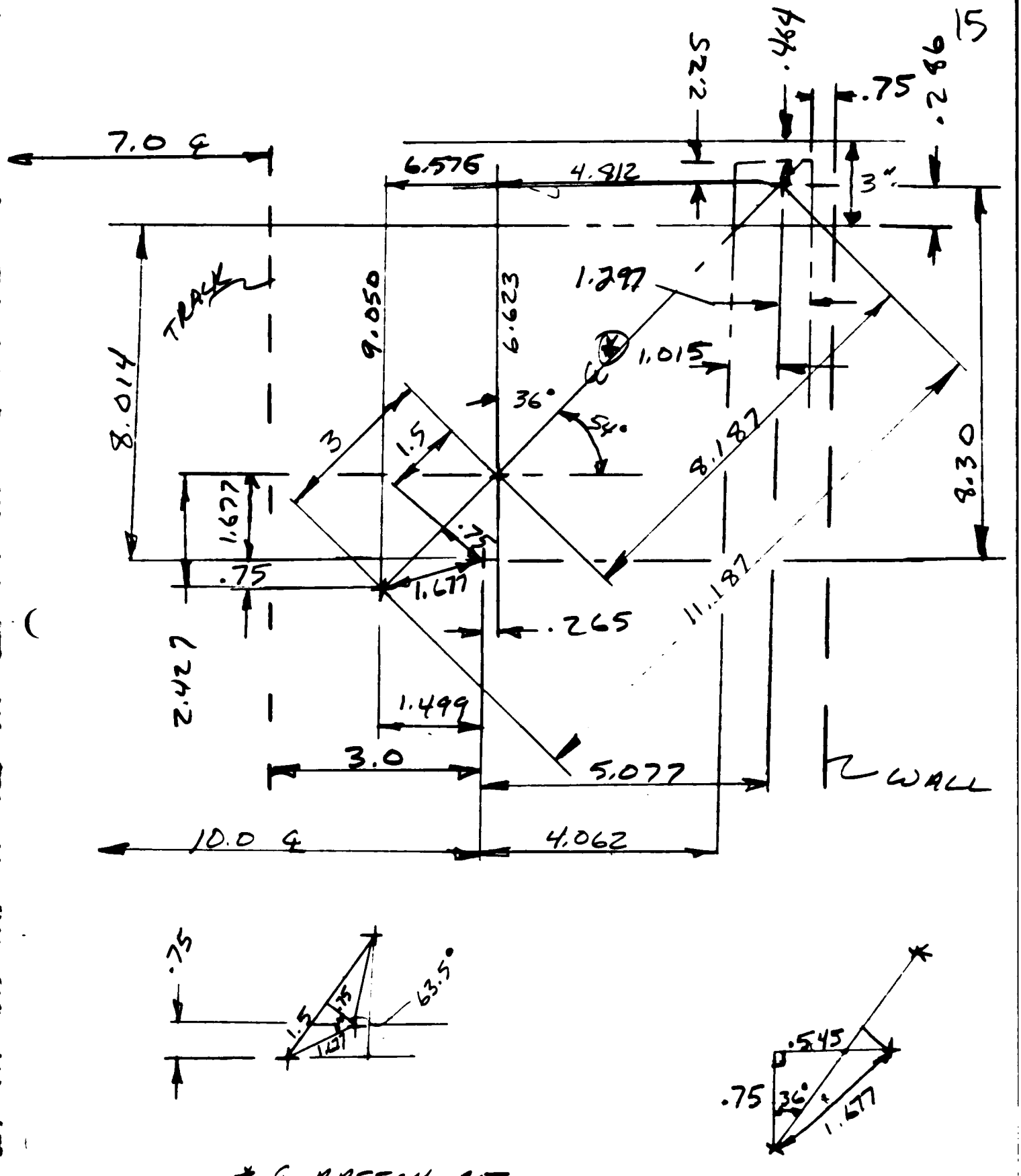
A = 2.76 × 3000 psi = 8283 =
1.875 DIA = (A 2.76)

FOR

$$\begin{array}{r} .276 \\ -\ .785 \\ \hline 1.975 \end{array} = 5925 =$$

10,000

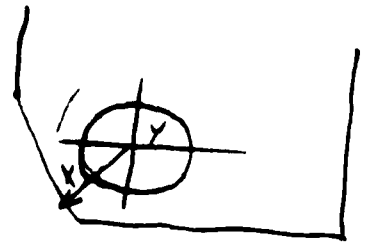
$$\begin{array}{r} 2.76 \\ -\ 1.227 \\ \hline 1.532 \end{array} = 4598 =$$


.225
.464
.75
.246
7.0 ℄
6.576
4.912
3"
TRACK
9.050
6.623
1.297
1.015
8.014
36°
54°
3
1.5
8.187
8.30
1.677
1.677
.75
.265
11.187
2.427
1.499
3.0
5.077
WALL
10.0 ℄
4.062
.75
1.5
1.677
63.5°
.545
.75
36°
1.677
* ℄ BREECH ACT.

Break out end

$\frac{7}{8}$ DIA PIN IN ALUM BLOCK

A = .75

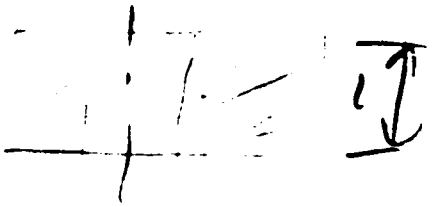


X = 1.625 R

Y = .875 PIN

DEPT 1"

P = 8000 #



$\frac{8000}{.75} = 10.666 = S$

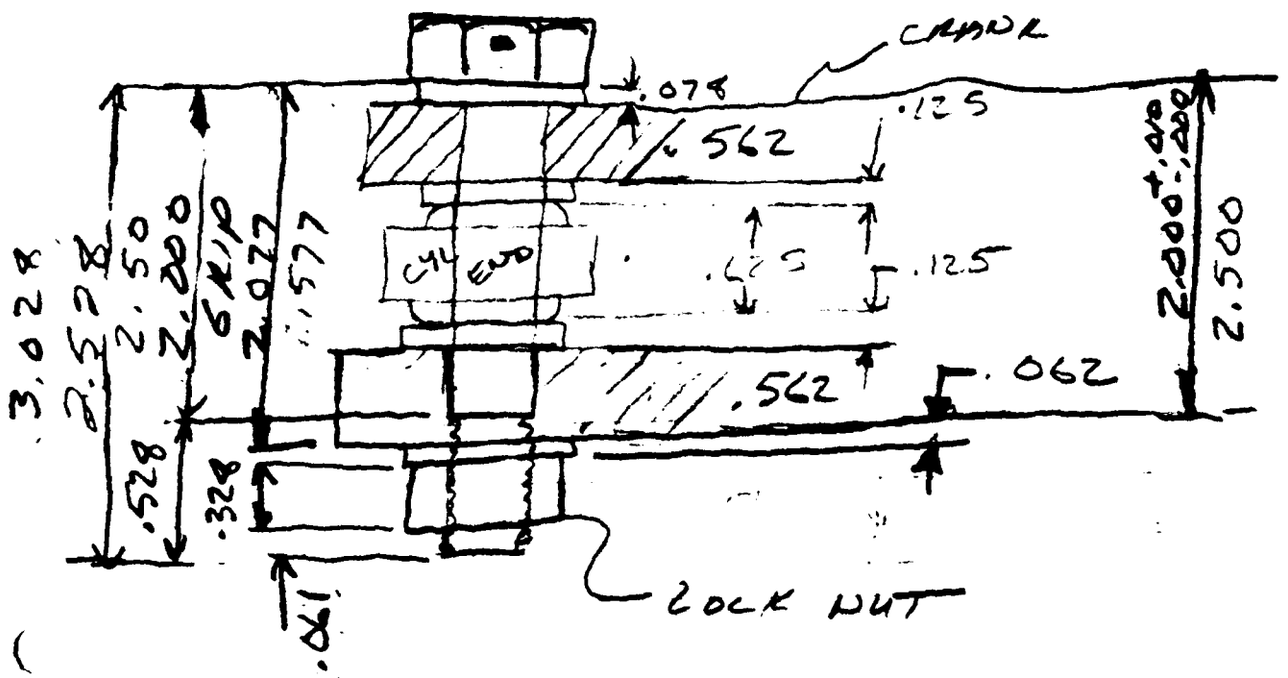
$\frac{23,080}{10,666}$

2.16 TO 1

Y 40,000 (.577) = 23,080

ASSY OF CRANK ON BREECH ACC.

BOLT & NUT



TOL LG

GRIP

2.778 LG NAS 6208 32 - 40

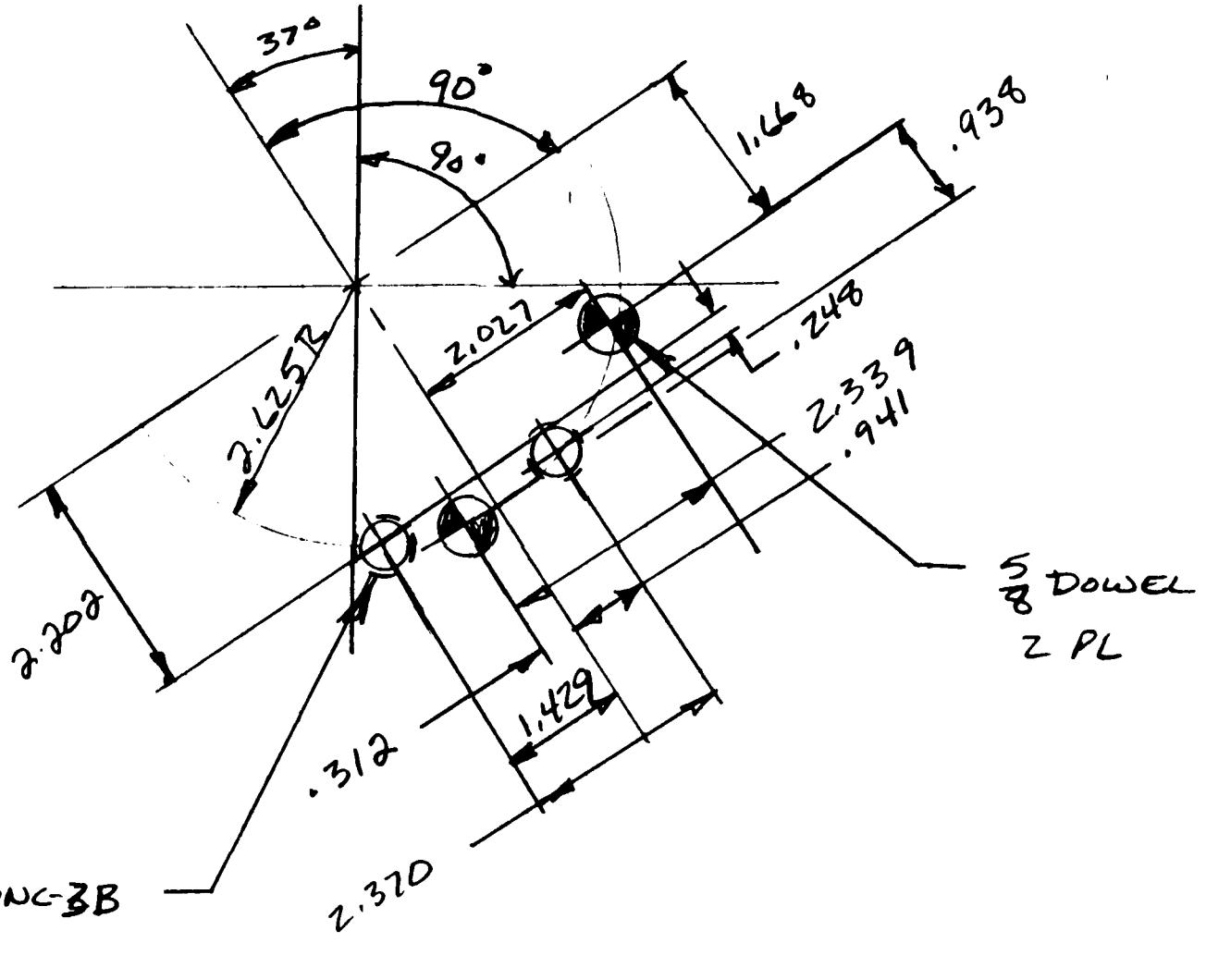
1/2 - 20 UNF

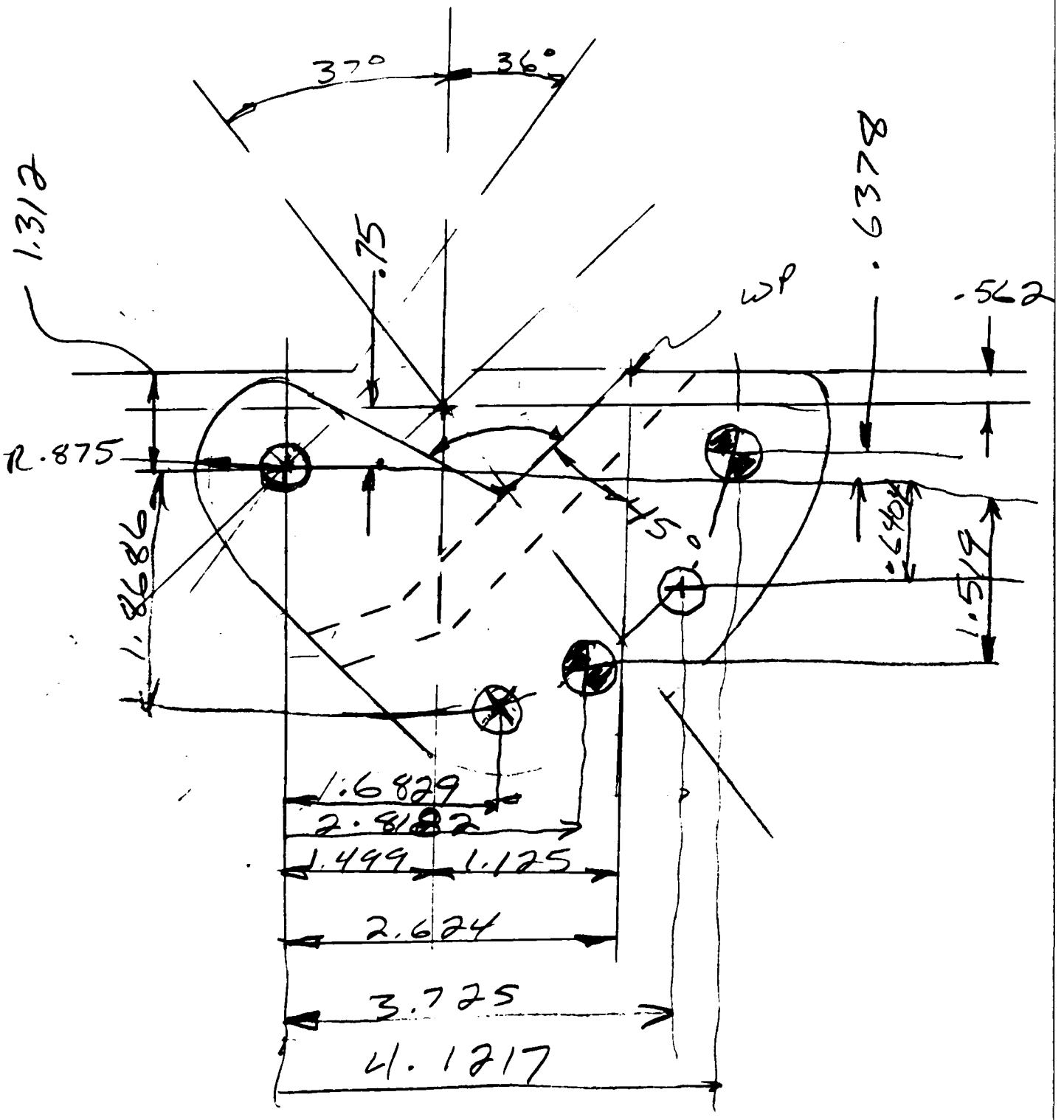
NUT MS 21083 - N8

.078	.085
2.000	2.010
.062	.067
.328	.328
2.468	2.490 MAX

2.528	2.528
-.015	+.015
2.513	2.543
2.490	2.468
.023	.065

CRANE

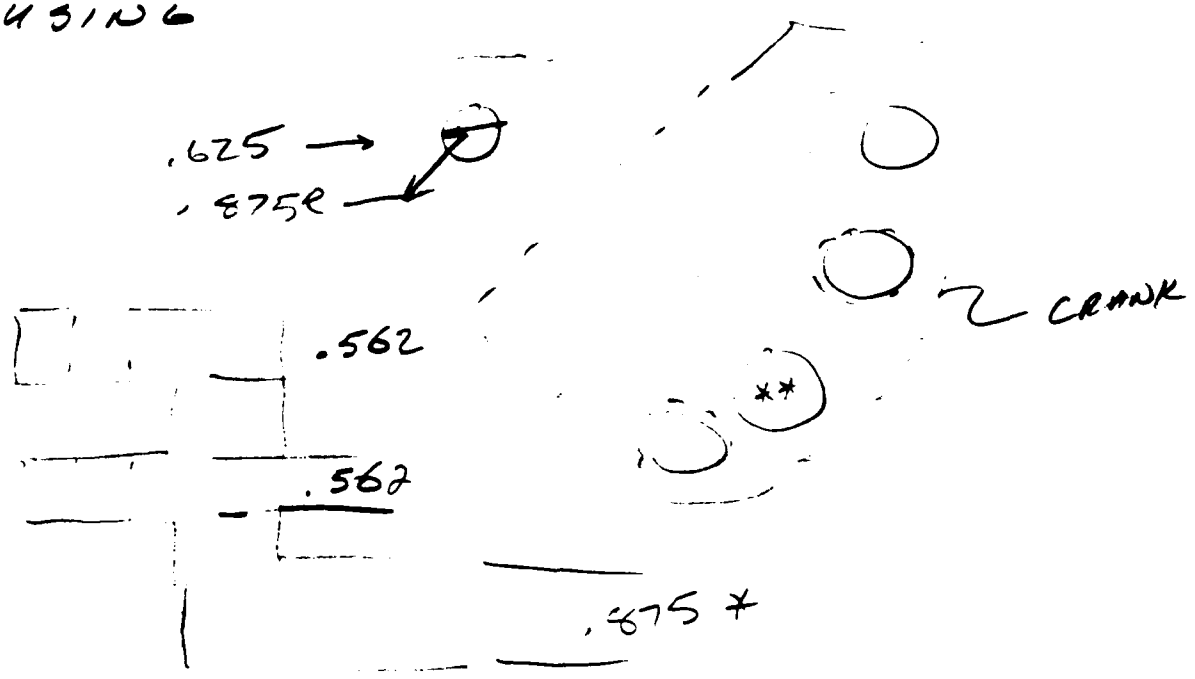

37°
90°
90°
1.668
.938
.249
2.027
2.425R
2.339
.941
2.202
5/8 DOWEL
2 PL
1.429
.312
2.320
1/2-13UNC-3B
2 PL


37°
36°
1.312
.75
.6378
WP
.562
R.875
1.8686
45°
.640
1.519
1.6829
2.8182
1.499
1.125
2.624
3.725
4.1217

½" DIA PIN IN ACT & ROD END

½ = A. = .1963 $\frac{8000\#}{.1963}$ = 40,743 = S

USING



A = $\begin{array}{r} .675 \\ -.250 \\ \hline .625 \end{array}$ X .562 = .351 X 4 1.405

$\frac{8000}{1.405}$ = 5,693

40,000 (.577) = $\frac{23080}{5693}$ = 4,053 TO 1

.485 X .625 X 2 = .351
.562 X .625 X 2 = .606
.957

$\frac{8000}{.957}$ = $\frac{23080}{5357}$ S. FACTOR 2.7(TO 1

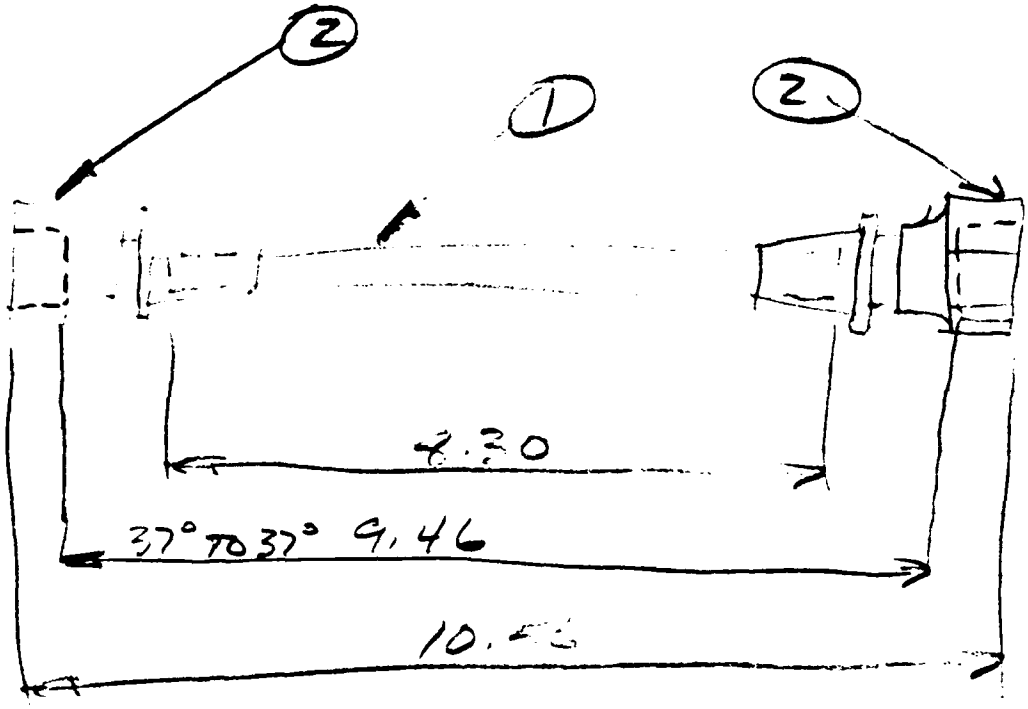
BREECH

T-1258037/A 002

RETURN

HOSE ASSY

(16)



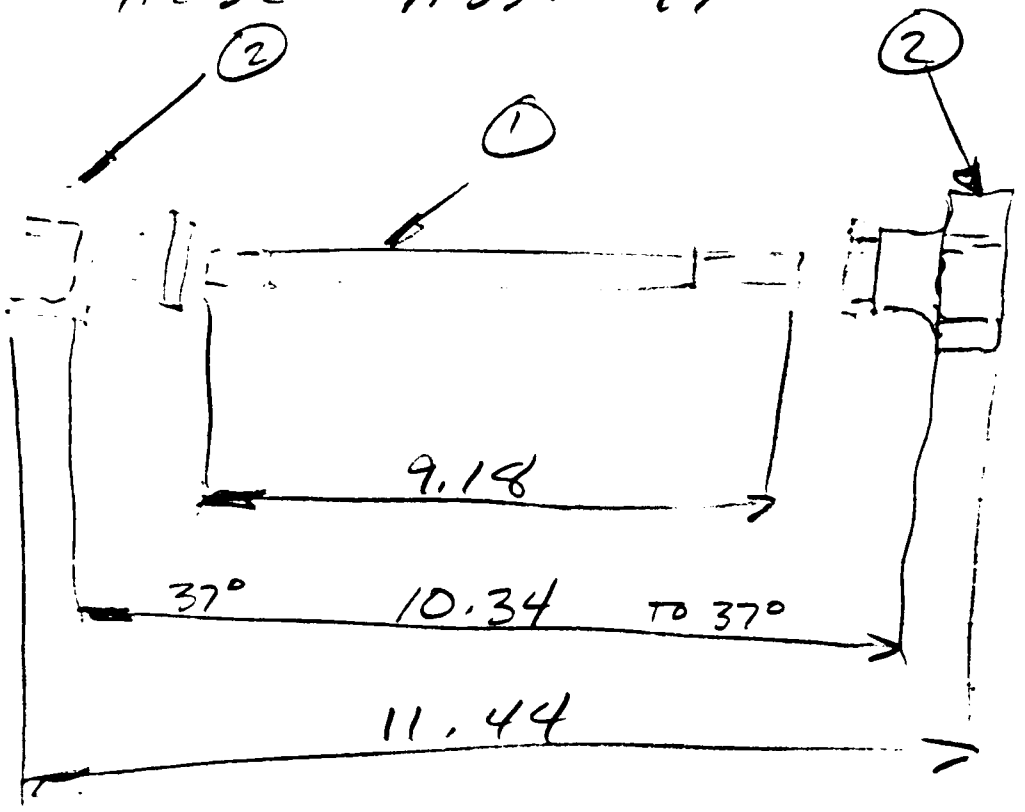
ITEM	NAME	QTY	SPEC	WT	TOL WT	PART #
1	HOSE	1	AERQ 2807-4 X 8.3 LG	.04	.04	
2	FITTING STR	2				

T-1258603T/A 001 22

GREEN

PRESSURE (TOP)

HOSE ASSY 17



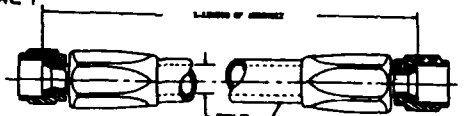
ITEM	NAME	QTY	DIS	WT	TOT WT	PART
1	HOSE	1	AERO 2907-4 X 9.18 LG	.05	.05	
2	FITTING	2				

DRAWING SIZE B

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL

DASH NO.	TUBE OD REF.	HOSE ID	END FITTING A	END FITTING B	FITTING MATERIAL	LENGTH INCHES	HOSE MATERIAL	REF. PART NO.	COMMENTS	USE:
202	4	.19	STR 37°	STR 37°	S. STL	10.56	TEFLON		AEROQUIP 2807-4 (C-190600-4)	BREECH ACTUATOR
001	4	.19	STR 37°	STR 37°	S. STL	11.44	TEFLON		AEROQUIP 2907-4 (C-190600-4)	BREECH ACTUATOR

END FITTING A



END FITTING B

PART NO.

NEXT ASSY	USED ON
APPLICATION	

MECHANICAL PROPERTIES	
YP	
TS	
EL2	
RA	
BH	
RH	

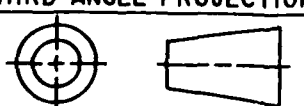
DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON DECIMALS ±

FRACTIONS ± ANGLES ±

THIRD ANGLE PROJECTION



ORIGINAL DATE OF DRAWING

DRAFTSMAN	CHECKER
1-10-87	
ENGR	ENGR
ENGR	ENGR

U.S. ARMY
ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
DOVER, NEW JERSEY 07801-5001

HOSE ASSY. - HYDRAULIC

SIZE	FSCM NO.	
B	19200	T-12586037 /A
SCALE	UNIT WT.	SHEET 1 OF 1

SMCAR FORM 66, 1 JUN 86(TEMP) REPLACES ARRADCOM FORM 66, AUG 77, WHICH MAY BE USED UNTIL EXHAUSTED

23

PART NUMBERS: 12585716, Elevation Actuator
12585712, 12585713 Equilibration Actuators
12585720, Equilibration Accumulator

DESCRIPTION: ELEVATION AND EQUILIBRATION

STATUS:

Elevation -

All critical parameters for the elevation actuator (TDP, Dwg. 12585716) have been determined and are presented to the extent complete in the Technical Data Package.

Since the design and analysis of the elevation actuator is highly dependent on the design of the equilibration system, the work in this area was performed integrally with equilibration analysis and is presented as such in the following pages of this section.

Additional elevation cylinder analysis that led to the current design is also contained in a Tube Laying Accuracy report found in section C/260.

Equilibration -

All critical design parameters for the two equilibration actuators (TDP, Dwgs. 12585712, 12585713) and accumulator (TDP, Dwg. 12585720) have been determined through analysis and are shown in the TDP drawings to the extent the TDP is finished.

A complete report summarizing the equilibration (and elevation) system design and analysis is found in the following pages of this section. This information includes analysis objectives, geometry, model initial conditions, torque calculations, static and dynamic analyses with both energy recovery and manual energy usage, variable names for program ELEVATION.BAS, program module descriptions and program listings.

Also included in this section are the final equilibration and elevation analysis results as of March 13, 1987. These results are for the current system geometry as well as component weights, CG's and inertias.

AUTHORS: John Green, Sean Marek

LT-ANALYSIS (96120)
IORE (9512)

JOHN GREEN'S NOTES ON LTHD

ELEVATION / EQUILIBRATION ANALYSIS

AS OF 10 DEC 86.

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ANALYSIS OBJECTIVES

Given the geometry of the Lightweight Towed Howitzer Demonstrator (LTHD), our objectives with this analysis are to size the:

Equilibration cylinders
Elevation cylinders
Equilibration accumulator

keeping in mind these time cycle constraints:

When moving both up and down (elevating and depressing), want to go:

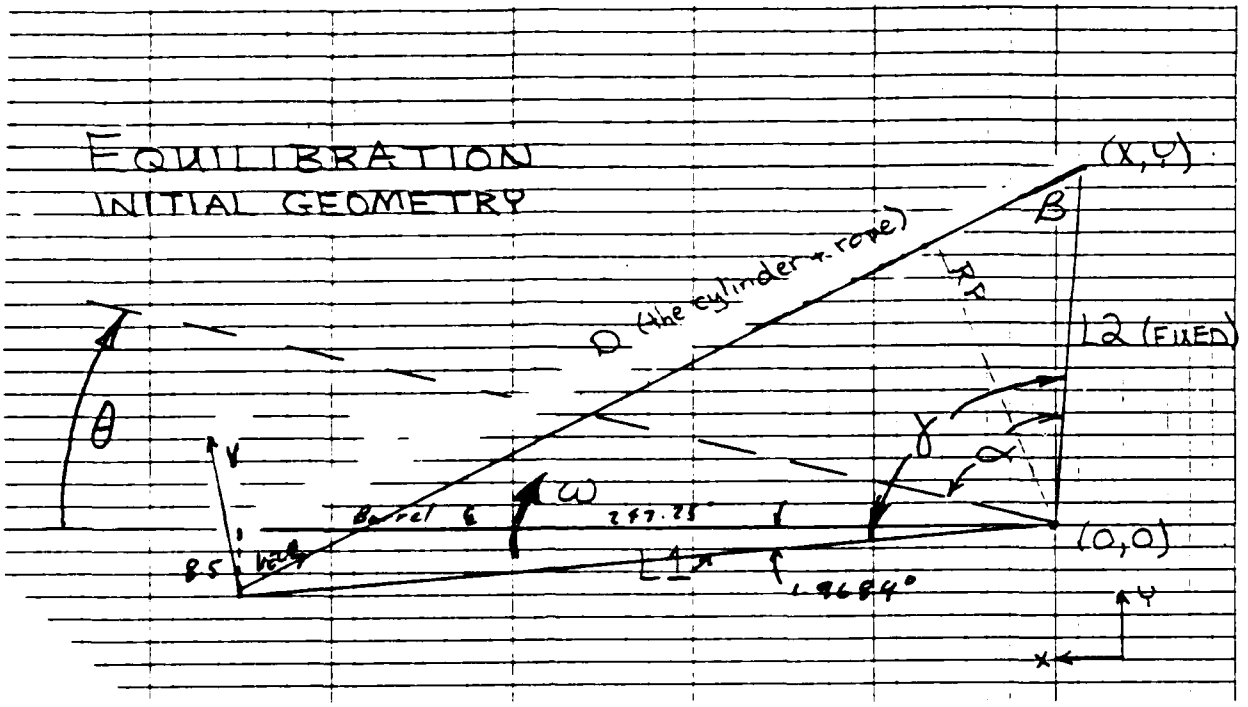
from	to	in
600 MILS (33.75°)	800 MILS (45.0°)	2 seconds
	and	
600 MILS (33.75°)	1300 MILS (73.125°)	10 seconds

The idea is for the equilibration system to balance most of the weight of the howitzer barrel so that the manual elevation system will be able to position it. The BASIC program has been written to generate the torque of the barrel due to gravity (TGRAV) versus the torque provided by the equilibrator (TEQUIL); in this case we want TGRAV to equal TEQUIL as closely as possible.

To determine the torques around the trunnion pivot point (assigned the X-Y coordinate of (0,0) for this analysis), geometry from the equlibration and elevation systems is used to find the torque "arms" perpendicular to the force on the cylinders. The main input variable for both systems is THETA, the angle at which the barrel is elevated from horizontal.

GEOMETRY DETERMINATION

Equilibration System



Given X, Y, L1, and THETA (note direction of the X-axis):

$L2 = SQRT(X^2 + Y^2)$

$GAMMA = ARCTAN(-X / Y) + 90° + 1.9689°$

$ALPHA = GAMMA - THETA$

From the Law of Cosines:

$D = SQRT(L1^2 + L2^2 - 2*L1*L2 * COS(ALPHA))$

From the Law of Sines:

$BETA = ARCSIN(L1 * SIN(ALPHA) / D)$

$RP = L2 * SIN(BETA)$

$= L2 * L1 * SIN(ALPHA) / D$

where RP is the perpendicular intercept needed to determine torque (TEQUIL) along D.

To determine the flowrate through the equilibration cylinder (FLOWEQUIL), the angular velocity (OMEGA) is computed from the angular acceleration of the barrel:

$$\text{ANGACCEL} = \text{TORQUE} / I$$

$$\text{OMEGA}_{now} = \text{OMEGA}_{previous} + (\text{ANGACCEL} * \text{timestep})$$

From the geometry, the velocity (VELD) along D is found to be:

$$\text{VELD} = \frac{L1 * \text{OMEGA} * \sin(\alpha lpha_a) + L2}{D}$$

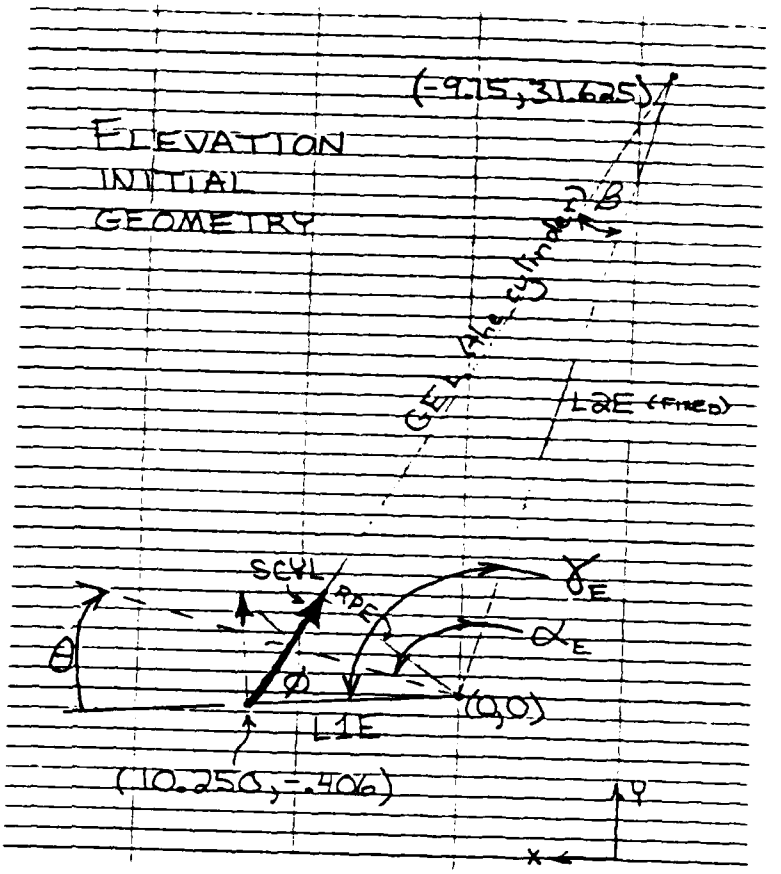
$$\text{FLOWEQUIL} = \text{VELD} * \text{AREA}_{equil\ cylinder}$$

Elevation System

L1E = 10.258

L2E = 33.094

γ_E = ~~165.13°~~ 109.40°



Given L1E and L2E, from their coordinates:

GAMMAE = ~~165.13°~~ 109.40°

ALPHAE = GAMMAE - THETA

From the Law of Cosines:

GEL = SQRT($L1E^2$ + $L2E^2$ - 2*L1E*L2E * COS(ALPHAE))

From the Law of Sines:

SIN(BETAE) = L1E* SIN(ALPHAE) / GEL

RPE = L2E* SIN(BETAE)

where RPE is the perpendicular intercept needed to determine torque (TELEV) along GEL.

Since VAX BASIC does not have the ARCSIN function built in, BETA may be found by this formula:

$$BETA = ARCTAN \left(\frac{SIN(BETAE)}{(1.0 - (SIN(BETAE))^2)^2} \right)$$

PHI = 180° - BETA - ALPHAE

To determine the flowrate through the elevation cylinder (FLOWELEV), use the same angular velocity (OMEGA) as for the equilibration system.

The velocity (SCYL) along GEL is found to be:

$$SCYL = L1E * OMEGA * COS(90^{\circ} - PHI)$$

$$FLOWELEV = SCYL * AREA2_{elev\ cylinders}$$

INITIAL CONDITIONS

Both dynamic and static analyses execute module 7000 of the BASIC code which interpolates from a Nitrogen real gas table to find:

The mass of the gas (MOLE) in the equilibration accumulator.

The volume of gas (VCOMP) to be pumped into the equilibration cylinder to get it to the right ~~charge~~ pressure. This volume is to compensate for pressure changes due to fluctuating ambient temperatures.

The initial entropy (ENTO) of the nitrogen in the accumulator.

Assuming the Nitrogen accumulator was charged in a lab at the ideal temperature of ~~72°~~ F and a specified charge pressure (for example, 3,000 PSI), interpolate from the Nitrogen table to get the specific volume (VOL) of the gas initially in the accumulator.

Given the volume of the equilibrator accumulator (VE), use this VOL to find the mass (MOLE) of the gas in the accumulator:

$$MOLE = VE / VOL \qquad \text{(LB-mass)}$$

Now given the ambient temperature and pressure conditions, interpolate from the Nitrogen table for a new VOL in order to find VCOMP (the compensation volume) to be pumped into the cylinder to get it to the right ~~charge~~ pressure. These computations are based on the gun at 0 degrees elevation.

$$VCOMP = VE - VOL*MOLE - ((DO - DF) * AREA1)$$

Next the variables get reset, based on the gun at THETAO elevation:

$$VOLO = \frac{VE - VCOMP - ((DS - DF) * AREA1)}{MOLE}$$

Given the initial temperature (TEMP = TEMPO = $T_{ambient}$) and specific volume (VOL = VOLO), interpolate from the Nitrogen table to get the initial pressure (PRESSO) and entropy (ENTO) of the nitrogen in the accumulator.

For dynamic analysis, entropy is assumed to remain constant. ENTO is thereby used only for Nitrogen table interpolation purposes to track the pressure changes.

(NOTE: The initial Nitrogen table we used was in SI units, so we converted all the values to English units except the entropy units because, in this analysis, entropy values are only used for interpolation.)

COMPUTING THE TORQUES

For each value of THETA (currently computed at 1° increments):

$$TGRAV = LCG * WT * COS(THETA)$$

For the equilibration system, find D for the given THETA. Use D to compute:

$$VOL = \frac{VE - ((D - DF) * AREA1) - VCOMP}{MOLE}$$

Use VOL to interpolate from the nitrogen table to get the pressure (PRESS), which is used in this equilibration system torque equation:

$$TEQUIL = (PRESS - PAMB) * AREA1 * RP$$

For the elevation system, find GEL for the given THETA. Use GEL to compute:

$$VOLUME = ABS((GELI - GEL) * AREA2)$$

The static analysis (for which these torques are found) is assumed to be:

- only elevating the barrel
- isothermal

Therefore the simple pressure/volume relation may be used:

$$PCYL = (PAI * VAI) / (VAI + VOLUME)$$

The elevation system torque is then:

$$TELEV = (PCYL - PAMB) * AREA2 * RPE$$

ANALYSES: STATIC & DYNAMIC

The BASIC program executes two analyses results:

The static analysis is initially run to optimize design parameters (charge pressure, sizing the accumulator, cylinders, pistons, etc.) before running the larger, more time consuming dynamic analysis.

The dynamic analysis then gives the cycle times as a result of these static analysis parameters.

There are two methods by which the barrel may be elevated/depressed:

The energy recovery option uses an accumulator (which gets pumped up by the gun recoil) to control barrel elevation.

The manual power option uses a ~~handcrank~~ hand pump to control barrel elevation.
This places the additional constraint on the system of a human only being able to maintain an input power of 0.3 horsepower.

Elevation Cylinder

First the program sets some controlling switches:

SWITCH = 0 when barrel is elevating
SWITCH = 1 when barrel is depressing

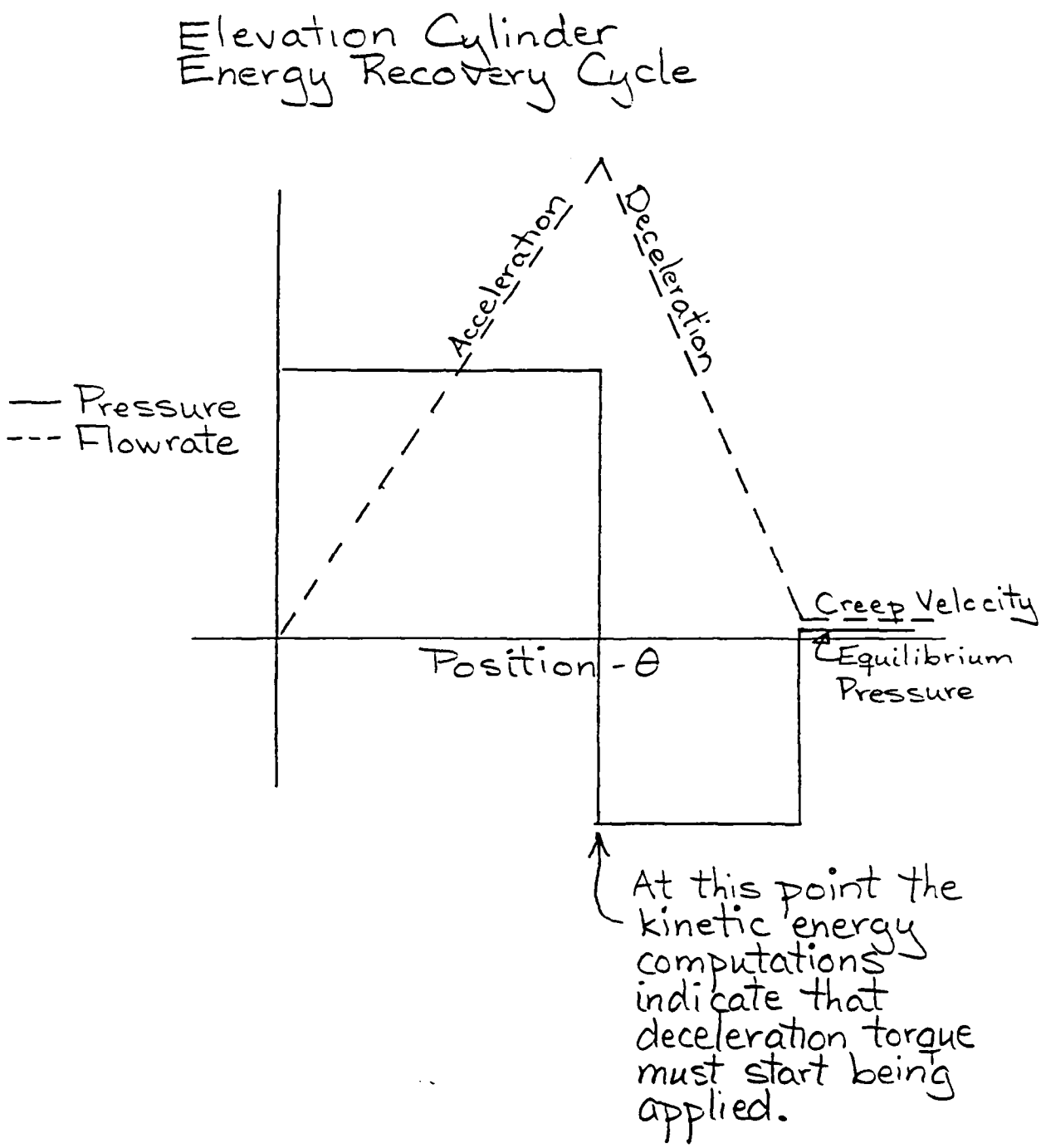
Flag 1 = 1 activates the deceleration routine

Flag 2 = 1 activates the creep speed routine to maintain a constant 2deg/sec until the cannon reaches its final elevation

A. For the Energy Recovery option:

1. ACCELERATION PHASE.

Use an energy recovery/storage accumulator (which gets pumped up by the gun recoil) to accelerate, and then decelerate, the system when it is elevating.



Track the kinetic energy (ENERGY) at each time step to determine when to "apply the brakes" (change from acceleration to deceleration).

So from the geometry, the angular velocity (OMEGA) is known at that time step and flags can be set accordingly.

The volume in the elevation cylinder may be figured from:

What comes out of the accumulator =

Volume change due to change in length of the cylinder

+

Volume initially expended from the accumulator (VOLUME1 = 0 for elevating.)

That is:

$$VOLUME = ABS((GELI - GEL) * AREA2) + VOLUME1$$

The pressure in the cylinder (PCYL) is computed from an equation based on the theoretical condition of an isentropic process ~~and~~ an ~~adiabatic~~, ideal gas (so temperature is eliminated as a variable).

That equation is: $P_1 V_1^n = P_2 V_2^n$

and

$$PCYL = \frac{PAI * VAI^n}{(VAI + VOLUME)^n} \qquad \text{where } n = 1.4$$

$$ENERGY = 0.5 * I * (OMEGA)^2$$

The torque (TSTOP) required to turn around and stop the acceleration (at that time step):

$$TSTOP = \frac{ENERGY}{ABS(THETA_{end} - THETA_{current}) - .008}$$

where the .008 radians is to assure a creep speed distance.

PSTOP is also figured as a function of TSTOP, even though it is really an (instantaneous) approximation.

$$PSTOP = PAMB + ABS(TSTOP / (AREA3 * RPE))$$

Torque on the elevation cylinder is also computed for this acceleration phase:

$$TELEV_{accel} = (PCYL - PAMB) * AREA2 * RPE$$

As soon as TSTOP or PSTOP exceed a maximum, FLAG1 is thrown and the program jumps down to the deceleration phase.

2. DECELERATION PHASE.

Here:

$$PCYL = -PSTOP * GAIN$$

where GAIN is a multiplier/constant input by the person running the program to compensate for a program limitation; the program cannot anticipate what will happen in future computations.

PCYL needs to be negative since pressure is now applied to the back side (AREA3) of the elevation cylinder piston.

$$TELEV_{decel} = (PCYL + PAMB) * AREA3 * RPE$$

As soon as the angular velocity (OMEGA) drops to or below the creep velocity (VMIN), the program jumps down to the creep velocity phase.

3. CREEP VELOCITY PHASE.

Once the barrel attains creep velocity, it is assumed that the constant speed yields balanced torques. Therefore:

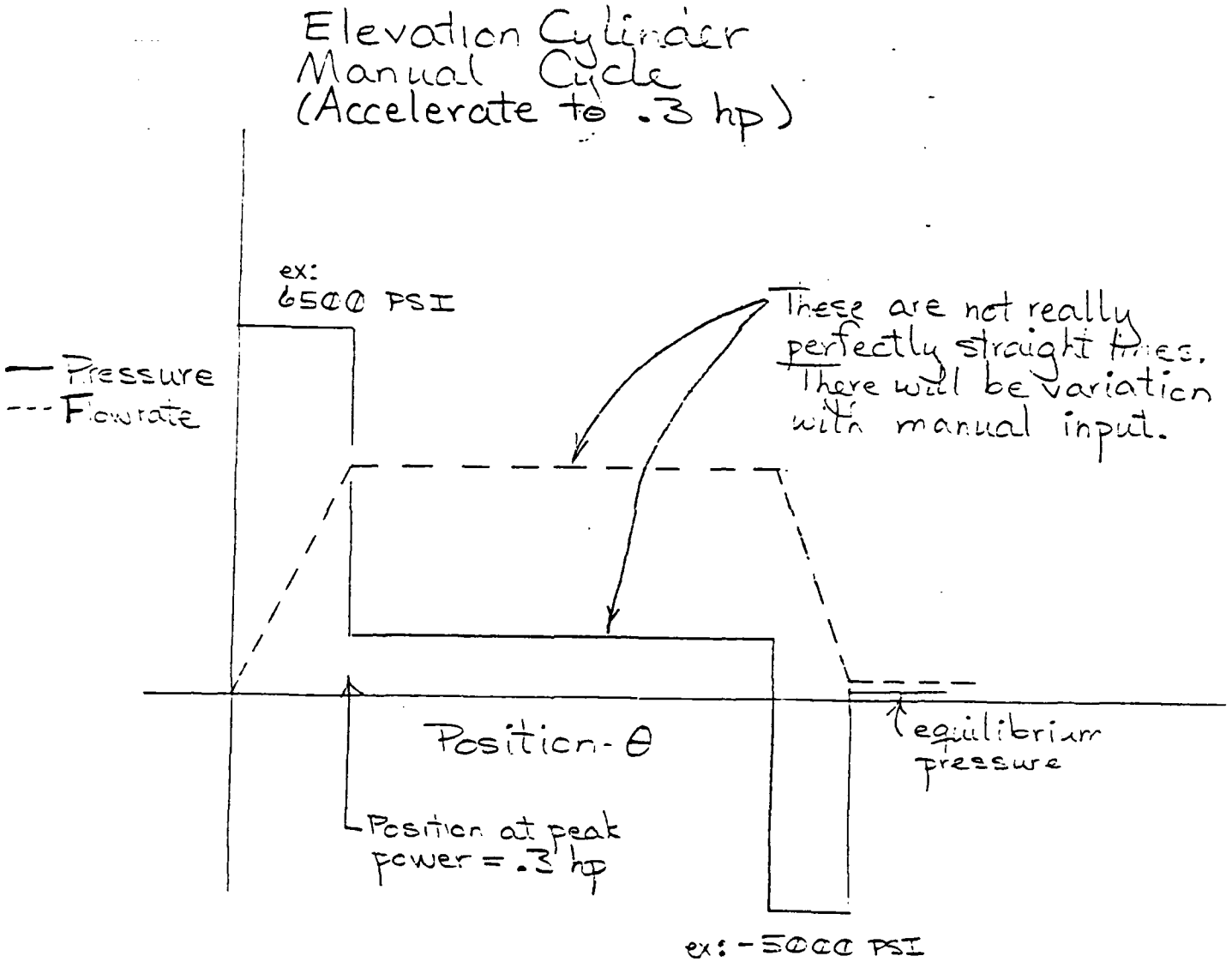
$$TELEV_{creep} = TGRAV - TEQUIL$$

Torque just required to keep it moving at constant speed.

$$PCYL = PAMB + (TELEV / (AREA2 * RPE))$$

B. For the Manual Power option there is the additional constraint of a human only being able to maintain an input power of 1/3 horsepower.

POWMAX = 0.3



From the geometry it is known that:

$$SCYL = L1E * OMEGA * COS(\frac{PI}{2} - PHI)$$

$$PCYL = PCYLMAX + PAMB$$

From a fluid handbook:

$$VEL_{cyl}\ (ft/s) = \frac{231 * \text{Flow Rate (GPM)}}{12 * 60 * \text{Net Area } (in^2)}$$

Therefore:

$$FLOWRATE = SCYL * AREA2 * 60 / 231$$

$$POWER\ (hp) = FLOWRATE * PCYL / (1714.0 * efficiency)$$

^Assume e = 100%

If POWER > 0.3 then reset the input pressure to maintain a constant power of 0.3 horsepower:

$$PCYL = PAMB + ABS(\ 0.3 * 1714.0 / FLOWRATE)$$

The following computations are the same as for the Energy Recovery option (Section A.):

$$ENERGY = 0.5 * I * (OMEGA)^2$$

The torque (TSTOP) required to turn around and stop the acceleration (at that time step):

$$TSTOP = \frac{ENERGY}{ABS(THETA_{end} - THETA_{current}) - .008}$$

where the .008 radians is to assure a creep speed distance.

PSTOP is also figured as a function of TSTOP, even though it is really an (instantaneous) approximation.

$$PSTOP = PAMB + (TSTOP / (AREA3 * REP)\ )$$

$$TELEV_{accel} = (PCYL - PAMB) * AREA2 * RPE$$

As soon as TSTOP or PSTOP exceed a maximum, FLAG1 is thrown and the program jumps down to the deceleration phase (Section A.2.).

VARIABLE NAMES FOR PROGRAM ELEVATION.BAS

VARIABLE	COMPUTATION UNITS	DESCRIPTION
A		COUNTER
ACC		NUMBER USED TO CHECK PRECISION OF ITERATION
ALPHA	RAD	ALPHA variable for equilibrator geometry
ALPHAE	RAD	ALPHA variable for elevation geometry
ANGACCEL	RAD/SEC^2	ANGULAR ACCELERATION OF THE BARREL
AREA1	IN^2	PISTON AREA - EQUILIBRATION CYLINDER
AREA2	IN^2	PISTON AREA - ELEVATION (SMALLER SIDE) * 2 CYLINDER
AREA3	IN^2	PISTON AREA - ELEVATION (LARGER SIDE) * 2 CYLINDER
B		COUNTER
BETA		BETA variable for geometry
BSS		
BV		
C		COUNTER
CNT		A COUNTER TO PRINT EVERY 100 DATA POINTS
D		COUNTER
D	IN	SIDE 3, EQUILIBRATION GEOMETRY (THE SLIDING LEG)
DATAOUT$	string	OUPUT FILE NAME
DEGTORAD		CONVERSION CONSTANT
DF	IN	D AT THETA = 72 DEGREES
DO	IN	D AT THETA = 0 DEGREES
DRIVER$	string	DRIVING FUNCTION OPTION VARIABLE
DS	IN	D AT THETA = THETAO
DT	SEC	TIME STEP
ENERGY	FT-LB	=.5*I*OMEGA^2,CURRENT KINETIC ENERGY OF BARREL ASSY
ENT		CURRENT ENTROPY OF THE EQUILIBRATION GAS
ENTO		INITIAL ENTROPY OF EQUIL GAS AT SIMULATION START
EPS		
EPSP		= EPS/8.0
FLAG1		
FLAG2		
FLOWELEV	GAL/MIN	FLOWRATE INTO ELEVATION CYLINDER
FLOWEQUIL	GAL/MIN	FLOWRATE INTO EQUILIBRATION CYLINDER
GAIN		A MULTIPLIER, HUMAN INPUT COMPENSATES FOR PRG LIMIT
GAMMA	RAD	GAMMA variable for equilibrator geometry
GAMMAE	RAD	GAMMA variable for elevation geometry
GEL	IN	SIDE 3, ELEVATION GEOMETRY (THE SLIDING LEG)
GELF	IN	GEL AT THE HIGHEST ANGLE
GELI	IN	AT THETA=0 FOR GOING UP, AT THETA=72 FOR GOING DOWN
GELO	IN	GEL AT THE LOWEST ANGLE
I	SLUG-FT^2	MASS MOMENT OF INERTIA OF THE BARREL
L1	IN	SIDE 1, EQUILIBRATION GEOMETRY
L1E	IN	SIDE 1, ELEVATION GEOMETRY
L2	IN	SIDE 2, EQUILIBRATION GEOMETRY
L2E	IN	SIDE 2, ELEVATION GEOMETRY
LCG	IN	= 13.56 FEET
MOLE	LB-mass	=VE/VOL, MASS OF GAS IN EQUILIBRATOR ACCUMULATOR
MS		
MV		
OMEGA	RAD/S	ANGULAR VELOCITY OF ELEVATION GEOMETRY
OMEGA1		
OMEGA1S		INITIAL CONDITIONS GIVEN TO THE ITERATION MODULE
OMEGA2		
OMEGA2S		

VARIABLE NAMES FOR PROGRAM ELEVATION.BAS

VARIABLE	COMPUTATION UNITS	DESCRIPTION
OPT$	string	OPTION STRING VARIABLE
PAI	LB/IN^2	INITIAL ENERGY STORAGE ACCUMULATOR GAS PRESSURE
PAMB	LB/IN^2	AMBIENT PRESSURE
PCHARGE	LB/IN^2	CHARGE PRESSURE
PCYL	LB/IN^2	CURRENT PRESSURE IN ELEVATION CYLINDER
PCYL1	LB/IN^2	
PCYL2	LB/IN^2	
PCYLMAX	LB/IN^2	MAX PRESSURE POSSIBLE DURING MANUAL OPERATION
PH		
PHI	RAD	ANGLE BETWEEN CYLINDER & BARREL
PISDIA	IN	ELEVATION CYLINDER PISTON DIAMETER
PL		
PO	LB/IN^2	EQUILIBRATION GAS PRESSURE AT THETA = 0
POWER		POWER BEING EXERTED BY ELEVATION CYLINDER
POWMAX	HP	MAXIMUM MANUAL POWER INPUT: 1/3 HP
PRESS	LB/IN^2	CURRENT PRESSURE OF EQULIBRATION PISTON
PRESS	LB/IN^2	PRESSURE AFTER EXTENDED TIME
PRESSO	LB/IN^2	INITIAL EQUILIBRATION GAS PRESSURE
PSTART	LB/IN^2	STARTING DECELERATION PRESSURE
PSTOP	LB/IN^2	OPTIMUM PRESSURE REQ'D TO STOP BARREL BEFORE THETAF
PSTOPMAX	LB/IN^2	=PSTART/GAIN, MAXIMUM ALLOWABLE STOPPING PRESSURE
RADTODEG		CONVERSION CONSTANT
RODDIA	IN	ROD DIAMETER, ELEVATION CYLINDER
RP	IN	PERPENDICULAR BISECTOR, EQUILIBRATION GEOMETRY
RPE	IN	PERPENDICULAR BISECTOR, ELEVATION GEOMETRY
S1H		variable used for interpolation
S1L		variable used for interpolation
S2H		variable used for interpolation
S2L		variable used for interpolation
SCYL	IN/S	SPEED (VELOCITY) OF THE ELEVATION CYLINDER
SH		
SH		
SINB		SIN OF THE BETA ANGLE, EQUILIBRATION GEOMETRY
SINBE		SIN OF THE BETA ANGLE, ELEVATION GEOMETRY
SL		
SL		
STME		CURRENT TIME GIVEN TO THE ITERATION MODULE
SWITCH		=0 FOR ELEVATING, =1 FOR DEPRESSING (ELEVATION CYL)
T		TIME INCREMENT TO BE GIVEN TO THE ITERATION MODULE
T1		TORQUE AT BEGINNING OF TIME STEP
T2		TORQUE AT END OF THE TIME STEP
TAMB	deg-F	OUTSIDE AMBIENT TEMP
TELEV	IN-LB	TORQUE EXERTED BY THE ELEVATION CYLINDER
TEMP	deg-F	=72 CURRENT TEMP
TEMPO	deg-F	INITIAL EQUILIBRATION GAS TEMP
TEQUIL	IN-LB	TORQUE EXERTED BY THE EQUILIBRATION CYLINDER
TGRAV	IN-LB	TORQUE EXERTED GRAVITY
TH		
THETA	RAD	INPUT ANGLE: ELEVATION OF THE BARREL
THETA1		
THETA1S		INITIAL CONDITIONS GIVEN TO THE ITERATION MODULE
THETA2		
THETA2S		

VARIABLE NAMES FOR PROGRAM ELEVATION.BAS

VARIABLE	COMPUTATION UNITS	DESCRIPTION
THETAF	RAD	HIGHEST ENDING ELEVATION (MAY BE 72 DEGREES)
THETAO	RAD	LOWEST STARTING ELEVATION (MAY BE 0 DEGREES)
THETAS	RAD	=THETAF FOR ELEVATING, =THETAO FOR DEPRESSING
TIMENOW$	string	CURRENT TIME
TL		
TM1	IN-LB	INITIAL MEAN FORCE GUESS
TM2	IN-LB	=(T2+T1)/2.0 , NEXT MEAN TORQUE GUESS
TME	SEC	TIME
TODAY$	string	TODAY'S DATE
TORQUE	IN-LB	=TELEV+TEQUIL-TGRAV, TOTAL TORQUE DETERMINED
TS1		
TS2		
TSTOP	IN-LB	OPTIMUM TORQUE REQ'D TO STOP BARREL BEFORE THETAF
TSTOPMAX	IN-LB	MAXIMUM DECELERATION/ALLOWABLE STOPPING TORQUE
TV1		variable used for interpolation
TV2		variable used for interpolation
V1H		variable used for interpolation
V1H		variable used for interpolation
V1L		variable used for interpolation
V1L		variable used for interpolation
V2H		variable used for interpolation
V2H		variable used for interpolation
V2L		variable used for interpolation
V2L		variable used for interpolation
VAI	IN^3	INITIAL ENERGY STORAGE ACCUMULATOR GAS VOLUME
VCOMP	IN^3	VOLUME OF FLUID USED TO COMPENSATE FOR TEMP CHANGE
VE	IN^3	VOLUME OF THE EQUILIBRATOR ACCUMULATOR
VELD	IN/S	VELOCITY ALONG D
VF	IN^3	FINAL VOLUME OF THE EQUILIBRATION GAS
VH		
VL		
VMIN	RAD/S	=.01 RAD/S, ANGULAR CREEP VELOCITY
VOL	IN^3/LBm	SPECIFIC VOLUME OF THE EQUILIBRATION GAS
VOLO	IN^3/LBm	INITIAL EQUILIBRATION GAS SPECIFIC VOLUME
VOLUME	IN^3	VOLUME OF FLUID USED SINCE START OF SIMULATION
VOLUME1	IN^3	AMT OF FLUID PUMPED INTO CYL AT END OF ELEVATING
WT	LBS	WEIGHT OF COMPONENTS TO BE ELEVATED/DEPRESSED

Program module descriptions

Line	Description
100	Main operating menu
185	Equilibration Modification Menu
370	Elevation modification menu
605	Simulation control menu
1000	Simulation controler
2000	Force, velocity, position, and acceleration iteration modul
3000	Torque Summing module
4000	Geometry determination module
5000	Equilibration torque module
6000	Elevation torque module
7000	initial conditions module
8000	Real gas data input module
9000	Gas table interpolation by pressure and temperat
10000	Gas table interpolation by specific volume and entropy
11000	Gas table interpolation by temperature and specific volume
12000	Static Simulation module
13000	Data ouput module
14000	Output file initialization module
15000	Overturning Torque calculation module

VARIABLE NAMES FOR PROGRAM ELEVATION.BAS

VARIABLE	COMPUTATION UNITS	DESCRIPTION
A		COUNTER
ACC		NUMBER USED TO CHECK PRECISION OF ITERATION
ALPHA	RAD	ALPHA variable for equilibrator geometry
ALPHAE	RAD	ALPHA variable for elevation geometry
ANGACCEL	RAD/SEC^2	ANGULAR ACCELERATION OF THE BARREL
AREA1	IN^2	PISTON AREA - EQUILIBRATION CYLINDER
AREA2	IN^2	PISTON AREA - ELEVATION (SMALLER SIDE) * 2 CYLINDERS
AREA3	IN^2	PISTON AREA - ELEVATION (LARGER SIDE) * 2 CYLINDERS
B		COUNTER
BETA		BETA variable for geometry
BSS		
BV		
C		COUNTER
CNT		A COUNTER TO PRINT EVERY 100 DATA POINTS
D		COUNTER
D	IN	SIDE 3, EQUILIBRATION GEOMETRY (THE SLIDING LEG)
DATAOUT$	string	OUPUT FILE NAME
DEGTORAD		CONVERSION CONSTANT
DF	IN	D AT THETA = 72 DEGREES
DO	IN	D AT THETA = 0 DEGREES
DRIVER$	string	DRIVING FUNCTION OPTION VARIABLE
DS	IN	D AT THETA = THETAO
DT	SEC	TIME STEP
ENERGY	FT-LB	=.5*I*OMEGA^2,CURRENT KINETIC ENERGY OF BARREL ASSY
ENT		CURRENT ENTROPY OF THE EQUILIBRATION GAS
ENTO		INITIAL ENTROPY OF EQUIL GAS AT SIMULATION START
EPS		
EPSP		= EPS/8.0
FLAG1		
FLAG2		
FLOWELEV	GAL/MIN	FLOWRATE INTO ELEVATION CYLINDER
FLOWEQUIL	GAL/MIN	FLOWRATE INTO EQUILIBRATION CYLINDER
GAIN		A MULTIPLIER, HUMAN INPUT COMPENSATES FOR PRG LIMIT
GAMMA	RAD	GAMMA variable for equilibrator geometry
GAMMAE	RAD	GAMMA variable for elevation geometry
GEL	IN	SIDE 3, ELEVATION GEOMETRY (THE SLIDING LEG)
GELF	IN	GEL AT THE HIGHEST ANGLE
GELI	IN	AT THETA=0 FOR GOING UP, AT THETA=72 FOR GOING DOWN
GELO	IN	GEL AT THE LOWEST ANGLE
I	SLUG-FT^2	MASS MOMENT OF INERTIA OF THE BARREL
L1	IN	SIDE 1, EQUILIBRATION GEOMETRY
L1E	IN	SIDE 1, ELEVATION GEOMETRY
L2	IN	SIDE 2, EQUILIBRATION GEOMETRY
L2E	IN	SIDE 2, ELEVATION GEOMETRY
LCG	IN	= 13.56 FEET
MOLE	LB-mass	=VE/VOL, MASS OF GAS IN EQUILIBRATOR ACCUMULATOR
MS		
MV		
OMEGA	RAD/S	ANGULAR VELOCITY OF ELEVATION GEOMETRY
OMEGA1		
OMEGA1S		INITIAL CONDITIONS GIVEN TO THE ITERATION MODULE
OMEGA2		
OMEGA2S		

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VARIABLE	COMPUTATION UNITS	DESCRIPTION
OPT$	string	OPTION STRING VARIABLE
PAI	LB/IN^2	INITIAL ENERGY STORAGE ACCUMULATOR GAS PRESSURE
PAMB	LB/IN^2	AMBIENT PRESSURE
PCHARGE	LB/IN^2	CHARGE PRESSURE
PCYL	LB/IN^2	CURRENT PRESSURE IN ELEVATION CYLINDER
PCYL1	LB/IN^2	
PCYL2	LB/IN^2	
PCYLMAX	LB/IN^2	MAX PRESSURE POSSIBLE DURING MANUAL OPERATION
PH		
PHI	RAD	ANGLE BETWEEN CYLINDER & BARREL
PISDIA	IN	ELEVATION CYLINDER PISTON DIAMETER
PL		
PO	LB/IN^2	EQUILIBRATION GAS PRESSURE AT THETA = 0
POWER		POWER BEING EXERTED BY ELEVATION CYLINDER
POWMAX	HP	MAXIMUM MANUAL POWER INPUT: 1/3 HP
PRESS	LB/IN^2	CURRENT PRESSURE OF EQULIBRATION PISTON
PRESS	LB/IN^2	PRESSURE AFTER EXTENDED TIME
PRESSO	LB/IN^2	INITIAL EQUILIBRATION GAS PRESSURE
PSTART	LB/IN^2	STARTING DECELERATION PRESSURE
PSTOP	LB/IN^2	OPTIMUM PRESSURE REQ'D TO STOP BARREL BEFORE THETAF
PSTOPMAX	LB/IN^2	=PSTART/GAIN, MAXIMUM ALLOWABLE STOPPING PRESSURE
RADTODEG		CONVERSION CONSTANT
RODDIA	IN	ROD DIAMETER, ELEVATION CYLINDER
RP	IN	PERPENDICULAR BISECTOR, EQUILIBRATION GEOMETRY
RPE	IN	PERPENDICULAR BISECTOR, ELEVATION GEOMETRY
S1H		variable used for interpolation
S1L		variable used for interpolation
S2H		variable used for interpolation
S2L		variable used for interpolation
SCYL	IN/S	SPEED (VELOCITY) OF THE ELEVATION CYLINDER
SH		
SH		
SINB		SIN OF THE BETA ANGLE, EQUILIBRATION GEOMETRY
SINBE		SIN OF THE BETA ANGLE, ELEVATION GEOMETRY
SL		
SL		
STME		CURRENT TIME GIVEN TO THE ITERATION MODULE
SWITCH		=0 FOR ELEVATING, =1 FOR DEPRESSING (ELEVATION CYL)
T		TIME INCREMENT TO BE GIVEN TO THE ITERATION MODULE
T1		TORQUE AT BEGINNING OF TIME STEP
T2		TORQUE AT END OF THE TIME STEP
TAMB	deg-F	OUTSIDE AMBIENT TEMP
TELEV	IN-LB	TORQUE EXERTED BY THE ELEVATION CYLINDER
TEMP	deg-F	=72 CURRENT TEMP
TEMPO	deg-F	INITIAL EQUILIBRATION GAS TEMP
TEQUIL	IN-LB	TORQUE EXERTED BY THE EQUILIBRATION CYLINDER
TGRAV	IN-LB	TORQUE EXERTED GRAVITY
TH		
THETA	RAD	INPUT ANGLE: ELEVATION OF THE BARREL
THETA1		
THETA1S		INITIAL CONDITIONS GIVEN TO THE ITERATION MODULE
THETA2		
THETA2S		

```
LLLLLLLLLL     5555555555555555555555555555555555555555555555555555     LLLLLLLLLL
LLLLLLLLLL     Digital Equipment Corporation - VAX/VMS Version V4.4      LLLLLLLLLL
LLILLLLLLL     5555555555555555555555555555555555555555555555555555     LLLLLLLLLL
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                M   M   999     000   EEEEE   000   55555
                MM MM  9   9   0   0  E      0   0  5
                M M M  9   9   0  00  E      0  00  555
                M   M   9999   0 0 0  EEEE   0 0 0    5
                M   M      9   00  0  E      00  0      5
                M   M      9   0   0  E      0   0  5   5
                M   M   999     000   EEEEE   000    555

      EEEEE  L      EEEEE  V   V   AAA   TTTTT   III    OOO   N   N
      E      L      E      V   V  A   A    T      I    O   O  N   N
      E      L      E      V   V  A   A    T      I    O   O  NN  N
      EEEE   L      EEEE   V   V  A   A    T      I    O   O  N N N
      E      L      E      V   V  AAAAA    T      I    O   O  N  NN
      E      L      E       V V   A   A    T      I    O   O  N   N
      EEEEE  LLLLL  EEEEE    V    A   A    T     III    OOO   N   N

                      SSSS   AAA   V   V    ;;     1
                     S      A   A  V   V    ;;    11
                     S      A   A  V   V           1
                      SSS   A   A  V   V    ;;     1
                         S  AAAAA  V   V    ;;     1
                   ..    S  A   A   V V      ;     1
                   ..  SSSS  A   A    V      ;    111
```

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File _HSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]ELEVATION.SAV;1 (3594,16,0), last revised on 9-DEC-1986 12:47, is a 66 block sequential file owned by UIC [310,300]. The records are variable length with implied (CR) carriage control. The longest record is 121 bytes.

Job ELEVATION (620) queued to LNSYS on 15-DEC-1986 11:13 by user M90E05, UIC [310,300], under account M93 at priority 100, started on printer _VENUS$TXA6: on 15-DEC-1986 11:13 from queue LNSYS.

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LLLLLLLLLL     5555555555555555555555555555555555555555555555555555     LLLLLLLLLL
LLLLLLLLLL     Digital Equipment Corporation - VAX/VMS Version V4.4      LLLLLLLLLL
  LLLLLLLL     5555555555555555555555555555555555555555555555555555     LLLLLLLLLL
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10 rem PROGRAM TO SIMULATE THE ELEVATION OF THE LTHD
12 rem October/November 1986  John E. Green/Leanna K. Peterson
14 DIM T(14),P(50),S(50,14),V(50,14)
16 TODAY$    = DATE$(0)
18 DATAOUT$ = "NONE"
20 RAD_TO_DEG = 180.0 / PI
22 DEG_TO_RAD = PI / 180.0
24 PAMB      = 14.7
26 THETAO    = 0.0
28 THETAF    = 72.0 * DEG_TO_RAD
30 DT        = 0.001
31 CNTMAX%   = 500
32 I         = 41230.
34 AREA1     = 5.7
36 PISDIA    = 3.25
38 PAI       = 3000.0 + PAMB
40 VAI       = 2500.0
42 TSTOPMAX = 10000*12
44 PSTART    = 3000.0 + PAMB
46 PCYLMAX   = 3000.0 + PAMB
48 POWMAX    = 0.3
50 TAMB      = 70.0
52 PO        = 5000.0 + PAMB
54 VE        = 1200.0
56 EPS       = 1.0
58 EPSP      = EPS/8.0
60 DRIVER$   = "ENERGY RECOVERY"
62 WT        = 6077.0
64 GAIN      = 0.65
66 PCHARGE   = 2700.0 + 14.7
68 RODDIA    = 1.5
70 X         = -2.0
72 Y         = 35.5
74 L1        = 247.4
76 L2        = SQRT(X^2+Y^2)
78 LCG       = 161.748
80 L1E       = 10.258
82 L2E       = 33.09
84 GAMMA     = ATN(-X/Y) + PI/2.0
86 GAMMAE    = 109.4029 * DEG_TO_RAD
87 DRAG = .8
88 ORIFICE = .1
89 L3=57.002
90 L4=233.6862
91 LAMC=1.2747
92 LAMS=.2864
93 L3E=51.8913
94 L4E=240.3595
95 LAMEC=1.0552
96 LAMES=.4003
97 ACCMAX=1
99 GOSUB 8000
100 rem MAIN MENU
105 PRINT "WOULD YOU LIKE TO:"
110 PRINT "1. VIEW/MODIFY EQUILIBRATION PARAMETERS"
115 PRINT "2. VIEW/MODIFY ELEVATION CYLINDER PARAMETERS"
120 PRINT "3. VIEW/MODIFY OVERALL SYSTEM PARAMETERS"
125 PRINT "4. RUN DYNAMIC SIMULATION"
130 PRINT "5. RUN STATIC SIMULATION"
135 PRINT "6. END SESSION"
140 PRINT "(ENTER NUMBER)"
145 INPUT OPT1
```

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150 IF OPT1 = 1 THEN GOSUB 185
155 IF OPT1 = 2 THEN GOSUB 370
160 IF OPT1 = 3 THEN GOSUB 605
165 IF OPT1 = 4 THEN GOSUB 1000
170 IF OPT1 = 5 THEN GOSUB 12000
175 IF OPT1 = 6 THEN GOTO 16000
180 GOTO 100
185 rem EQUILIBRATION PARAMETER MODIFICATION MODULE
190 PRINT "WOULD YOU LIKE TO:"
195 PRINT "1. CHANGE PISTON AREA, CURRENT =                                    ";A
200 PRINT "2. CHANGE EQUILIBRATOR VOLUME, CURRENT =                            ";V
205 PRINT "3. CHANGE AMBIENT TEMPERATURE, CURRENT =                            ";T
210 PRINT "4. CHANGE AMBIENT PRESSURE, CURRENT =                               ";P
215 PRINT "5. CHANGE STARTING PRESSURE AT 0 Q.E., CURRENT =                    ";P
220 PRINT "6. CHANGE CHARGE PRESSURE AT 72 DEG. F AND 14.7 PSI, CURRENT =      ";P
225 PRINT "7. CHANGE X LOCATION OF WIRE ROPE, CURRENT =                        ";X
230 PRINT "8. CHANGE Y LOCATION OF WIRE ROPE, CURRENT =                        ";Y
235 PRINT "9. RETURN TO MAIN MENU"
240 PRINT "(ENTER NUMBER)"
245 INPUT OPT2
250 IF OPT2 <> 1 THEN GOTO 260
255 INPUT "ENTER PISTON AREA (INCH^2) ";AREA1
260 IF OPT2 <> 2 THEN GOTO 270
265 INPUT "ENTER EQUILIBRATOR VOLUME (INCH^3) ";VE
270 IF OPT2 <> 3 THEN GOTO 280
275 INPUT "ENTER AMBIENT TEMPERATURE (deg-F) ";TAMB
280 IF OPT2 <> 4 THEN GOTO 290
285 INPUT "ENTER AMBIENT PRESSURE (PSI) ";PAMB
290 IF OPT2 <> 5 THEN GOTO 305
295 INPUT "ENTER STARTING PRESSURE (PSI) ";PO
300 PO=PO+PAMB
305 IF OPT2 <> 6 THEN GOTO 320
310 INPUT "ENTER CHARGE PRESSURE (PSI) ";PCHARGE
315 PCHARGE=PCHARGE+14.7
320 IF OPT2 <> 7 THEN GOTO 340
325 INPUT "ENTER X LOCATION (IN) ";X
330 L2    = SQRT(X^2+Y^2)
335 GAMMA = ATN(-X/Y) + PI/2.0
340 IF OPT2 <> 8 THEN GOTO 360
345 INPUT "ENTER Y LOCATION (IN) ";Y
350 L2    = SQRT(X^2+Y^2)
355 GAMMA = ATN(-X/Y) + PI/2.0
360 IF OPT2 = 9 THEN RETURN
365 GOTO 185
370 rem CHANGE ELEVATION CYLINDER PARAMETERS MODULE
375 PRINT "WOULD YOU LIKE TO:"
380 PRINT " 1. CHANGE DRIVING FUNCTION, CURRENT =                              ";DR
385 PRINT " 2. CHANGE MAXIMUM MANUAL PRESSURE, CURRENT =                       ";PC
390 PRINT " 3. CHANGE CONTROL ORIFICE SIZE, CURRENT =                          ";OR
395 PRINT " 4. CHANGE STARTING DECELERATION PRESSURE, CURRENT =                ";PS
400 PRINT " 5. CHANGE MAXIMUM DECELERATION TORQUE, CURRENT =                   ";TS
405 PRINT " 6. CHANGE ENERGY STORAGE ACCUMULATOR GAS VOLUME, CURRENT =         ";VA
410 PRINT " 7. CHANGE ENERGY STORAGE ACCUMULATOR GAS PRESSURE, CURRENT =       ";PA
415 PRINT " 8. CHANGE ELEVATION CYLINDER PISTON DIAMETER, CURRENT =            ";PI
420 PRINT " 9. CHANGE GAIN VALUE, CURRENT =                                    ";GA
425 PRINT "10. CHANGE ROD DIAMETER, CURRENT =                                  ";RO
430 PRINT "11. RETURN TO MAIN MENU"
435 PRINT "(ENTER NUMBER) "
440 INPUT OPT3
445 IF OPT3 <> 1 THEN GOTO 485
450 PRINT "WOULD YOU LIKE TO USE:"
455 PRINT "1. MANUAL ELEVATION"
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460 PRINT "2. ENERGY RECOVERY ELEVATION"
465 PRINT "(ENTER NUMBER) "
470 INPUT OPT4
475 IF OPT4 = 1 THEN DRIVER$="MANUAL"
480 IF OPT4 = 2 THEN DRIVER$="ENERGY RECOVERY"
485 IF OPT3 <> 2 THEN GOTO 500
490 INPUT "ENTER PEAK MANUAL PRESSURE (PSI) ",PCYLMAX
495 PCYLMAX=PCYLMAX+PAMB
500 IF OPT3 <> 3 THEN GOTO 510
505 INPUT "ENTER CONTROL ORIFICE SIZE (IN) ",ORIFICE
510 IF OPT3 <> 4 THEN GOTO 525
515 INPUT "ENTER STARTING DECELERATION PRESSURE (PSI) ",PSTART
520 PSTART=PSTART+PAMB
525 IF OPT3 <> 5 THEN GOTO 540
530 INPUT "ENTER MAXIMUM DECELERATION TORQUE (FT-LB) ",TSTOPMAX
535 TSTOPMAX = TSTOPMAX * 12.0
540 IF OPT3 <> 6 THEN GOTO 550
545 INPUT "ENTER ACCUMULATOR GAS VOLUME (CU-IN) ",VAI
550 IF OPT3 <> 7 THEN GOTO 565
555 INPUT "ENTER ACCUMULATOR GAS PRESSURE (PSI) ",PAI
560 PAI=PAI+PAMB
565 IF OPT3 <> 8 THEN GOTO 575
570 INPUT "ENTER PISTON DIAMETER (IN) ",PISDIA
575 IF OPT3 <> 9 THEN GOTO 585
580 INPUT "ENTER GAIN ",GAIN
585 IF OPT3 <> 10 THEN GOTO 595
590 INPUT "ENTER ROD DIAMETER (IN) ",RODDIA
595 IF OPT3 = 11 THEN GOTO 100
600 GOTO 370
605 rem CHANGE SYSTEM PARAMETERS MODULE
610 PRINT "WOULD YOU LIKE TO:"
615 PRINT "1. CHANGE STARTING ELEVATION, CURRENT =      ";THETAO*RAD_TO_DEG
620 PRINT "2. CHANGE ENDING ELEVATION, CURRENT =        ";THETAF*RAD_TO_DEG
625 PRINT "3. CHANGE DATA SAMPLING INTERVAL, CURRENT = ";CNTMAX%
630 PRINT "4. CHANGE CONVERGENCE TOLERANCE, CURRENT = ";ACCMAX
635 PRINT "5. CHANGE DATA CAPTURE FILE NAME, CURRENT = ";DATAOUT$
640 PRINT "6. RETURN TO MAIN MENU"
645 PRINT "(ENTER NUMBER)"
650 INPUT OPT5
655 IF OPT5 <> 1 THEN GOTO 670
660 INPUT "ENTER STARTING ELEVATION (DEGREES) ",THETAO
665 THETAO=THETAO*DEG_TO_RAD
670 IF OPT5 <> 2 THEN GOTO 685
675 INPUT "ENTER ENDING ELEVATION (DEGREES) ",THETAF
680 THETAF=THETAF*DEG_TO_RAD
685 IF OPT5 <> 3 THEN GOTO 695
690 INPUT "ENTER DATA SAMPLING INTERVAL ",CNTMAX%
695 IF OPT5 <> 4 THEN GOTO 705
700 INPUT "ENTER CONVERGENCE TOLERANCE (FT-LB) ",ACCMAX
705 IF OPT5 <> 5 THEN GOTO 715
710 INPUT "ENTER NEW OUTPUT FILE NAME (INCLUDE EXTENSION) ",DATAOUT$
715 IF OPT5 =  6 THEN RETURN
720 GOTO 605
1000 rem PERFORM SIMULATION MODULE
1005 rem
1006 SWITCH1=0
1007 TEMPP=0
1008 ALAST=1
1009 BLAST=13
1010 IF DATAOUT$ <> "NONE" THEN GOSUB 13000
1015 rem
1020 CNT%     = 0
```

```
1025 PSTOPMAX = PSTART/GAIN
1030 TSTOPP   = TSTOPMAX/GAIN
1035 rem SINCE THERE ARE 2 CYLINDERS, MULTIPLY THE AREA BY 2:
1040 AREA2    = 2.0  *  PI * ((PISDIA^2/4.0) - (RODDIA^2/4.0))
1045 AREA3    = 2.0  *  PI * PISDIA^2/4.0
1050 INPUT "DO YOU WISH TO SIMULATE DEPRESSION ALSO (Y/N) ", OPT$
1055 VOLUME1  = 0
1060 FLAG1    = 0
1065 FLAG2    = 0
1070 THETAS   = THETAF
1075 VMIN     = 0.034907
1080 GOSUB 7000
1085 rem GOTO 1170
1090 GELI=GELO
1095 PRINT ""
1100 PRINT "ELEVATION CYCLE"
1105 PRINT "TIME","ELEVATION","ELEVATION","EQUILIBRATOR","ANGULAR","OVERTURN"
1110 PRINT "","","PRESSURE","PRESSURE","VELOCITY","TORQUE"
1115 PRINT "(SEC)","(DEG)","(PSI)","(PSI)","(DEG/SEC)","(FT-LB)"
1120 IF DATAOUT$ <> "NONE" THEN PRINT #5; ""
1125 IF DATAOUT$ <> "NONE" THEN PRINT #5; "ELEVATION CYCLE"
1130 IF DATAOUT$ <> "NONE" THEN PRINT #5; "TIME","ELEVATION","ELEVATION","EQU
1135 IF DATAOUT$ <> "NONE" THEN PRINT #5; "","","PRESSURE","PRESSURE","VELOCI
1140 IF DATAOUT$ <> "NONE" THEN PRINT #5; "(SEC)","(DEG)","(PSI)","(PSI)","(D
1145 IF DATAOUT$ <> "NONE" THEN PRINT #5; ""
1150 rem
1155 rem OPEN & INITIALIZE THE OUTPUT FILES:
1160 GOSUB 14000
1165 rem
1170 PRINT ""
1175 rem TME=CURRENT TIME
1180 TME      = 0
1185 rem THETA1 AND OMEGA1 = CONDITIONS AT BEGINNING OF TIME STEP
1190 SWITCH% = 0
1195 THETA1   = THETAO
1200 OMEGA1   = 0
1205 rem T= TIME INCREMENT TO BE GIVEN TO ITERATION MODULE
1210 rem DT=CURRENT TIME STEP
1215 T        = DT
1220 rem THETA1S AND OMEGA1S = INITIAL CONDITIONS GIVEN TO ITERATION MODULE
1225 THETA1S = THETA1
1230 OMEGA1S = OMEGA1
1235 rem STME= CURRENT TIME GIVEN TO ITERATION MODULE
1240 STME     = TME
1245 rem GO TO FORCE ITERATION MODULE:
1250 GOSUB 2000
1255 THETA2   = THETA2S
1260 OMEGA2   = OMEGA2S
1265 rem GO TO NEXT TIME STEP
1270 CNT%     = CNT% +1
1275 IF CNT% <> CNTMAX% THEN GOTO 1330
1280 CNT%     = 0
1285 PRINT TME,THETA*RAD_TO_DEG,PCYL-PAMB,PRESS-PAMB,OMEGA2*RAD_TO_DEG,OVERTU
1290 IF DATAOUT$ <> "NONE" THEN PRINT #5; TME,THETA*RAD_TO_DEG,PCYL-PAMB,PRES
1295 rem
1310 PRINT #6  USING "####.#####", TME;
1312 PRINT #6  USING "#####.#####", THETA*RAD_TO_DEG
1315 PRINT #7, TME, PCYL-PAMB, PRESS-PAMB
1320 PRINT #8, TME, FLOWELEV, FLOWEQUIL
1325 rem
1330 IF THETA2 >= THETAF THEN GOTO 1360
1335 IF OMEGA2 <= 0 THEN GOTO 1360
```

```
1340 THETA1  = THETA2
1345 OMEGA1  = OMEGA2
1350 TME     = TME + DT
1355 GOTO 1215
1360 rem GUN DEPRESSION ROUTINE
1361 SWITCH1=0
1362 TEMPP=0
1365 IF (OPT$ = "N") or (OPT$ = "n") THEN GOTO 1575
1370 IF SWITCH% = 1 THEN GOTO 1560
1375 FLAG1   = 0
1380 FLAG2   = 0
1385 TEMP    = TAMB
1390 OMEGA2  = 0
1395 THETA2  = THETAF
1400 rem GO TO DATA BASED ON TEMP & SPECIFIC VOLUME MODULE:
1405 GOSUB 11000
1406 GOSUB 9000
1410 ENTO    = ENT
1415 PRINT ""
1420 PRINT "PRESSURE AFTER EXTENDED TIME = ";PRESS
1421 PRINT "ELEVATION CYLINDER STROKE = ";ABS(GELF-GELO)
1422 PRINT "TEMPERATURE COMPENSATION VOLUME = ";VCOMP
1425 PRINT ""
1430 INPUT DUMMY
1435 PRINT "DEPRESSION CYCLE"
1440 PRINT "TIME","ELEVATION","ELEVATION","EQUILIBRATOR","ANGULAR","OVERTURN"
1445 PRINT "","","PRESSURE","PRESSURE","VELOCITY","TORQUE"
1450 PRINT "(SEC)","(DEG)","(PSI)","(PSI)","(DEG/SEC)","(FT-LBS)"
1455 PRINT ""
1460 IF DATAOUT$ <> "NONE" THEN PRINT #5; "PRESSURE AFTER EXTENDED TIME = ";P
1461 IF DATAOUT$ <> "NONE" THEN PRINT #5; "ELEVATION CYLINDER STROKE = ";ABS(
1462 IF DATAOUT$ <> "NONE" THEN PRINT #5; "TEMPERATURE COMPENSATION VOLUME =
1465 IF DATAOUT$ <> "NONE" THEN PRINT #5; ""
1470 IF DATAOUT$ <> "NONE" THEN PRINT #5; "DEPRESSION CYCLE"
1475 IF DATAOUT$ <> "NONE" THEN PRINT #5; "TIME","ELEVATION","ELEVATION","EQU
1480 IF DATAOUT$ <> "NONE" THEN PRINT #5; "","","PRESSURE","PRESSURE","VELOCI
1485 IF DATAOUT$ <> "NONE" THEN PRINT #5; "(SEC)","(DEG)","(PSI)","(PSI)","(D
1490 IF DATAOUT$ <> "NONE" THEN PRINT #5; ""
1495 rem
1500 rem REINITIALIZE:
1505 VOLUME1 = VOLUME
1510 THETA1  = THETAF
1515 OMEGA1  = 0
1520 REM TME     = 0
1525 THETAS  = THETAO
1530 VMIN    = -VMIN
1535 GELI    = GELF
1540 SWITCH% = 1
1545 rem USING "NEGATIVE" AREAS TO REVERSE THE SIGN OF THE TORQUE:
1550 AREA2   = -2.0  * PI * PISDIA^2/4.0
1555 AREA3   = -2.0  * PI * ((PISDIA^2/4.0) - (RODDIA^2/4.0))
1560 IF THETA2 <= THETAO THEN GOTO 1575
1565 GOTO 1340
1570 rem
1575 CLOSE #5, #6, #7, #8
1580 RETURN
2000 rem FORCE ITERATION MODULE
2001 LOOP%=1
2005 rem THETA AND OMEGA = CONDITIONS SENT TO FORCE DETERMINATION MODULES
2010 THETA   = THETA1S
2015 OMEGA   = OMEGA1S
2020 rem GO TO FORCE DETERMINATION MODULE:
```

```
2025 GOSUB 3000
2030 PCYL1  = PCYL
2035 rem T1 = TORQUE AT BEGINNING OF TIME STEP
2040 rem TORQUE = TOTAL TORQUE DETERMINED BY FORCE MODULES
2045 T1     = TORQUE
2050 rem TM1=INITIAL MEAN FORCE GUESS
2055 TM1    = T1
2060 rem ANGACCEL = ANGULAR ACCELERATION OF THE BARREL (RAD/SEC^2)
2065 rem I        = MASS MOMENT OF INERTIA OF BARREL (SLUG-FT^2)
2070 rem NOTE:      TM1 MUST BE IN FT-LB UNITS:
2075 ANGACCEL     = (TM1 / 12.0) / I
2080 OMEGA2S= OMEGA1S +  ANGACCEL * T
2085 THETA2S= THETA1S +  OMEGA1S * T  +  0.5 * ANGACCEL * T^2
2090 THETA  = THETA2S
2095 OMEGA  = OMEGA2S
2100 rem GO TO FORCE DETERMINATION MODULE:
2105 GOSUB 3000
2110 PCYL2  = PCYL
2115 IF PCYL2 < 0 THEN GOTO 2125
2120 GOTO 2130
2125 IF PCYL1 > 0 THEN GOTO 2190
2130 IF PCYL2 > 0 THEN GOTO 2140
2135 GOTO 2145
2140 IF PCYL1 < 0 THEN GOTO 2190
2145 rem T2 = TORQUE AT THE END OF THE TIME STEP
2150 T2     = TORQUE
2155 rem TM2= NEXT MEAN TORQUE GUESS
2160 TM2    = (T2+T1)/2
2165 rem ACC= NUMBER USED TO CHECK PRECISION OF ITERATION
2170 ACC    = ABS(TM2-TM1)
2175 IF ACC <= ACCMAX THEN GOTO 2190
2180 TM1    = TM2
2181 IF LOOP% >= 1000 THEN PRINT "CONVERGENCE FAILURE, ACCMAX = ";ACCMAX
2182 IF LOOP% >= 1000 THEN GOTO 100
2183 LOOP%=LOOP%+1
2185 GOTO 2075
2190 RETURN
3000 rem FORCE DETERMINATION MODULE
3005 rem GO TO GEOMETRY DETERMINATION MODULE:
3010 GOSUB 4000
3015 rem GO TO EQUILIBRATOR FORCE DETERMINATION MODULE:
3020 GOSUB 5000
3025 rem GO TO ELEVATION CYLINDER FORCE DETERMINATION MODULE:
3030 GOSUB 6000
3035 rem TELEV = TORQUE EXERTED BY THE ELEVATION CYLINDER
3040 rem TEQUIL= TORQUE EXERTED BY THE EQUILIBRATION CYLINDER
3045 rem TGRAV = TORQUE EXERTED BY GRAVITY
3046 REM GOTO OVERTURNING TORQUE MODULE
3047 GOSUB 15000
3049 TORQUE   = TELEV + TEQUIL - TGRAV
3065 RETURN
4000 rem GEOMETRY DETERMINATION MODULE
4010 rem WT = WEIGHT OF COMPONENTS TO BE ELEVATED/DEPRESSED, LBS
4020 rem SEE SKETCHES FOR DEFINITIONS OF THE FOLLOWING PARAMETERS.
4030 rem D, RP, GEL, RPE ARE IN INCHES NOW (5 NOV 86  LKLP).
4040 rem
4050 rem THE FOLLOWING VARIABLES DEFINE THE EQUILIBRATION
4060 rem     CYLINDER POSITION/PARAMETERS
4070 ALPHA  = GAMMA - THETA + .0344
4080 DEQ    = (SQRT(L1^2 + L2^2 -  2 * L1*L2 * COS(ALPHA)))
4090 SINB   = L1 * SIN(ALPHA) / DEQ
4100 IF SINB => 1 THEN BETA=1.5708
```

```
4110 IF SINB => 1 THEN GOTO 4130
4120 BETA=ATN(SINB/SQR(1-SINB*SINB))
4130 RP      = L2 * SINB
4140 TGRAV   = LCG * COS(THETA) * WT
4145 DELT=PI-ALPHA-BETA
4150 rem
4160 rem THE FOLLOWING VARIABLES DEFINE ELEVATION / DEPRESSION
4170 rem      CYLINDER LOCATION
4180 ALPHAE = GAMMAE - THETA
4190 GEL     = (SQRT(L1E^2 + L2E^2 -  2.0 *L1E*L2E * COS(ALPHAE)))
4200 SINBE   = L1E * SIN(ALPHAE) / GEL
4210 IF SINBE => 1 THEN BETAE=1.5708
4220 IF SINBE => 1 THEN GOTO 4230
4221 BETAE=ATN(SINBE/SQR(1-SINBE*SINBE))
4230 RPE     = L2E * SINBE
4235 DELTE=PI-ALPHAE-BETAE
4240 BETA    = ATN(SINBE / SQR(1 - SINBE*SINBE))
4250 PHI     = PI - BETA - ALPHAE
4260 RETURN
5000 rem EQUILIBRATOR FORCE MODULE
5005 rem VOL = CURRENT SPECIFIC VOLUME OF THE EQUILIBRATION GAS
5010 rem VF  = FINAL VOLUME OF EQUILIBRATION GAS
5015 VOL     = (VE - ((DEQ-DF) * AREA1) - VCOMP) / MOLE
5020 rem ENT = CURRENT ENTROPY OF EQUILIBRATION GAS
5025 rem ENTO= INITIAL ENTROPY OF EQUILIBRATION GAS AT START OF SIMULATION
5030 ENT     = ENTO
5035 rem GO TO DATA BASED ON SPECIFIC VOLUME & ENTROPY MODULE:
5040 GOSUB 10000
5045 rem PRESS = CURRENT PRESSURE OF EQUILIBRATION GAS
5050 rem AREA1 = AREA OF EQUILIBRATION PISTON
5051 IF OMEGA = 0 THEN GOTO 5055
5052 TEQUIL=(PRESS-PAMB)*AREA1*RP-(OMEGA/ABS(OMEGA))*2500*RP
5053 GOTO 5060
5055 TEQUIL    = (PRESS-PAMB) * AREA1 * RP
5060 rem
5065 rem FLOWEQUIL = FLOWRATE THRU EQUILIBRATION CYLINDER (GAL/MIN)
5070 rem VELD      = VELOCITY ALONG D (IN/S).  FROM THE GEOMETRY:
5075 VELD      = L1 * OMEGA * (SIN(ALPHA) * L2)/DEQ
5080 FLOWEQUIL = (VELD * AREA1 * 60.0 / 231.0)
5085 RETURN
6000 rem ELEVATION CYLINDER FORCE MODULE
6005 rem PRINT "ELEVATION MODULE"
6010 REM IF DRIVER$ = "MANUAL" THEN GOTO 6210
6020 IF SWITCH% = 1 THEN GOTO 6055
6025 IF OMEGA <= VMIN THEN GOTO 6035
6030 GOTO 6070
6035 IF FLAG1 = 1 THEN GOTO 6380
6040 GOTO 6070
6055 IF OMEGA >= VMIN THEN GOTO 6065
6060 GOTO 6070
6065 IF FLAG1 = 1 THEN GOTO 6380
6070 IF DRIVER$ = "MANUAL" THEN GOTO 6210
6071 rem VOLUME=VOLUME OF FLUID USED SINCE START OF SIMULATION
6075 rem ENERGY RECOVERY ROUTINE
6080 rem FOR ELEVATION (& STATIC ANALYSIS), VOLUME1 = 0.0
6084 rem FOR DEPRESSION, VOLUME1 = volume from elevating
6085 SCYL      = L1E * OMEGA * COS((PI/2)-PHI)
6086 FLOWELEV = (SCYL * AREA2 * 60.0 / 231.0)
6090 VOLUME    = ABS((GELI-GEL) * AREA2) + VOLUME1
6095 rem PCYL = CURRENT PRESSURE IN ELEVATION CYLINDER
6100 rem PAI  = INITIAL GAS PRESSURE IN STORAGE ACCUMULATOR
6105 rem VAI  = INITIAL GAS VOLUME IN STORAGE ACCUMULATOR
```

```
6110 PCYL     = (((PAI)*VAI^1.4) / (VAI+VOLUME)^1.4)-.8*(FLOWELEV/(29.81*DRAG
6111 IF PCYL < 0 THEN PCYL=0
6115 rem ENERGY=CURRENT KINETIC ENERGY OF THE BARREL ASSEMBLY
6120 ENERGY   = 0.5 * I * OMEGA^2
6135 rem TSTOP= OPTIMUM TORQUE REQUIRED TO STOP THE BARREL BEFORE THETAF
6140 rem IF THETA >= THETAF THEN RETURN
6145 TSTOP    = (ENERGY/(ABS(THETAS-THETA)-.008))*12
6150 rem PSTOP= OPTIMUM PRESSURE REQUIRED TO STOP THE BARREL
6155 PSTOP    = ABS(TSTOP / (AREA3 * RPE)) + PAMB
6160 rem TSTOPMAX=MAXIMUM ALLOWABLE STOPPING TORQUE
6165 rem PSTOPMAX=MAXIMUM ALLOWABLE STOPPING PRESSURE
6170 IF TSTOP >= TSTOPP   THEN FLAG1=1
6175 IF PSTOP >= PSTOPMAX THEN FLAG1=1
6180 IF FLAG1 = 1 THEN GOTO 6355
6185 rem IF TSTOP >= TSTOPMAX THEN GOTO 6340
6190 rem IF PSTOP >= PSTOPMAX THEN GOTO 6340
6195 TELEV    = (PCYL-PAMB) * AREA2 * RPE
6200 rem PRINT TELEV/12.0,PCYL,"NORM",AREA2,RPE
6205 GOTO 6410
6210 rem MANUAL POWER ROUTINE
6215 rem PHI  = ANGLE BETWEEN CYLINDER AND BARREL
6220 rem SCYL = SPEED OF THE ELEVATION CYLINDER
6225 SCYL     = L1E * OMEGA * COS((PI/2)-PHI)
6230 rem PCYLMAX  = MAXIMUM PRESSURE POSSIBLE DURING MANUAL ELEVATION
6240 rem FLOWELEV = FLOWRATE INTO ELEVATION CYLINDER
6245 rem AREA2    = AREA OF ELEVATION CYLINDER PISTON
6250 FLOWELEV = ABS(SCYL * AREA2 * 60.0 / 231.0)
6251 PCYL     = PCYLMAX-.8*(FLOWELEV/(29.81*DRAG*ORIFICE^2))^2
6255 rem POWER    = POWER BEING EXERTED BY ELEVATION CYLINDER
6260 POWER    = ABS((FLOWELEV * (PCYL+.8*(FLOWELEV/(29.81*DRAG*ORIFICE^2))^2)
6265 VOLUME   = (GELI-GEL) * AREA2
6270 rem POWMAX   = MAXIMUM POWER ALLOWABLE FOR MANUAL ELEVATION (.3 hp)
6275 IF POWER > POWMAX THEN PCYL=ABS(POWMAX*1714/FLOWELEV)+PAMB-.8*(FLOWELEV/
6280 ENERGY   = 0.5 * I * OMEGA^2
6285 rem TSTOP    = OPTIMUM TORQUE REQUIRED TO STOP THE BARREL BEFORE THETAF
6290 TSTOP    = (ENERGY/(ABS(THETAS-THETA)-.008))*12
6295 rem PSTOP    = OPTIMUM PRESSURE REQUIRED TO STOP THE BARREL
6300 PSTOP=ABS(TSTOP/(AREA3*RPE))+PAMB
6305 rem TSTOPMAX = MAXIMUM ALLOWABLE STOPPING TORQUE
6310 rem PSTOPMAX = MAXIMUM ALLOWABLE STOPPING PRESSURE
6315 IF TSTOP >= TSTOPP THEN FLAG1=1
6320 IF PSTOP >= PSTOPMAX THEN FLAG1=1
6325 IF FLAG1 = 1 THEN GOTO 6355
6330 rem IF TSTOP >= TSTOPMAX THEN GOTO 6340
6335 rem IF PSTOP >= PSTOPMAX THEN GOTO 6340
6336 IF PCYL < 0 THEN PCYL=0
6341 TELEV  = (PCYL-PAMB) * AREA2 * RPE
6345 rem
6350 GOTO 6410
6355 rem DECELERATION ROUTINE
6360 PCYL   = -PSTOP * GAIN
6365 TELEV  = (PCYL+PAMB) * AREA3 * RPE
6370 rem PRINT TELEV/12.0,PCYL,"DECEL",AREA3,RPE
6375 GOTO 6410
6380 rem CREEP ROUTINE
6385 TELEV  = TGRAV - TEQUIL
6390 PCYL   = ((TELEV/RPE) / (AREA2)) + PAMB
6395 rem PRINT TELEV/12.0,PCYL,"CREEP",AREA2,RPE
6400 GOTO 6410
6410 RETURN
7000 rem INITIAL GAS AND GEOMETRIC DATA MODULE
7005 TEMP   = 72.0
```

```
7010 PRESS  = PCHARGE
7015 GOSUB 9000
7020 MOLE   = VE / VOL
7025 rem THETAO= INITIAL POSITION
7030 THETA  = 0.0
7035 GOSUB 4000
7040 rem DO     = INITIAL ROPE LENGTH
7045 DO     = DEQ
7050 rem THETAF=FINAL POSITION
7055 THETA  = 72.0 * DEG_TO_RAD
7060 GOSUB 4000
7065 DF     = DEQ
7070 rem DF     = FINAL ROPE LENGTH
7075 THETA  = THETAO
7080 GOSUB 4000
7085 DS     = DEQ
7090 GELO   = GEL
7095 THETA  = THETAF
7100 GOSUB 4000
7105 GELF   = GEL
7110 rem TEMP   = CURRENT TEMPERATURE
7115 TEMP   = TAMB
7120 rem TAMB   = OUTSIDE AMBIENT TEMPERATURE
7125 rem PO     = INITIAL EQUILIBRATION GAS PRESSURE
7130 PRESS  = PO
7135 GOSUB 9000
7140 rem TEMPO  = INITIAL EQUILIBRATION GAS TEMPERATURE
7145 rem PRESSO = INITIAL EQUILIBRATION GAS PRESSURE
7150 rem VOLO   = INITIAL EQUILIBRATION GAS SPECIFIC VOLUME
7155 rem VOL    = CURRENT EQUILIBRATION GAS SPECIFIC VOLUME
7160 rem ENTO   = INITIAL EQUILIBRATION GAS ENTROPY
7165 rem ENT    = CURRENT EQUILIBRATION GAS ENTROPY
7170 VCOMP  = VE - VOL*MOLE - ((DO-DF) * AREA1)
7175 VOLO   = (VE - VCOMP - ((DS-DF) * AREA1)) / MOLE
7180 TEMPO  = TAMB
7185 VOL    = VOLO
7190 TEMP   = TEMPO
7195 GOSUB 11000
7200 PRESSO = PRESS
7205 ENTO   = ENT
7210 RETURN
8000 rem DATA INPUT MODULE
8005 OPEN "NITROGEN.DAT" FOR INPUT AS FILE #1
8010 rem    OPEN "nitrogen.eng" FOR INPUT AS FILE #1
8015 INPUT #1,TITLE$
8020 INPUT #1,BLANK$
8025 INPUT #1,TEMP$,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),T(11),
8030 rem    INPUT #1,TEMP$,T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8)
8035 INPUT #1,BLANK$
8040 INPUT #1,PRESS$
8045 A=1
8050 INPUT #1,P(A),V(A,1),V(A,2),V(A,3),V(A,4),V(A,5),V(A,6),V(A,7),V(A,8),V(
8055 rem    INPUT #1,P(A),V(A,1),V(A,2),V(A,3),V(A,4),V(A,5),V(A,6),V(A,7),V(
8060 INPUT #1,S(A,1),S(A,2),S(A,3),S(A,4),S(A,5),S(A,6),S(A,7),S(A,8),S(A,9),
8065 rem    INPUT #1,S(A,1),S(A,2),S(A,3),S(A,4),S(A,5),S(A,6),S(A,7),S(A,8)
8070 IF A = 45 THEN GOTO 8095
8075 rem    IF A =  9 THEN GOTO 8095
8080 A=A+1
8085 INPUT #1,BLANK$
8090 GOTO 8050
8095 CLOSE #1
8100 RETURN
```

```
9000 rem DATA BASED ON TEMPERATURE AND PRESSURE MODULE
9005 PRESS=PRESS/100
9010 A=1
9015 IF P(A) >= PRESS THEN GOTO 9035
9020 A=A+1
9025 IF A > 45 THEN GOTO 9155
9030 GOTO 9015
9035 PH=P(A)
9040 PL=P(A-1)
9045 B=1
9050 IF T(B) >= TEMP THEN GOTO 9070
9055 B=B+1
9060 IF B > 14 THEN GOTO 9155
9065 GOTO 9050
9070 TH=T(B)
9075 TL=T(B-1)
9080 S1L=S(A-1,B-1)
9085 S1H=S(A-1,B)
9090 S2L=S(A,B-1)
9095 S2H=S(A,B)
9100 SL=S1L+((PRESS-PL)/(PH-PL))*((S2L-S1L))
9105 SH=S1H+((PRESS-PL)/(PH-PL))*((S2H-S1H))
9110 ENT SL+(ABS(TEMP-TL)/ABS(TH-TL))*ABS(SH-SL)
9115 V1L=V(A-1,B-1)
9120 V1H=V(A-1,B)
9125 V2L=V(A,B-1)
9130 V2H=V(A,B)
9135 VL=V1L+((PRESS-PL)/(PH-PL))*((V2L-V1L))
9140 VH=V1H+((PRESS-PL)/(PH-PL))*((V2H-V1H))
9145 VOL=VL+(ABS(TEMP-TL)/ABS(TH-TL))*ABS(VH-VL)
9150 GOTO 9160
9155 PRINT "DATA POINT OUT OF RANGE, PRESS = ";PRESS,"TEMP = ";TEMP
9160 PRESS=PRESS*100
9165 RETURN
10000 rem DATA BASED ON SPECIFIC VOLUME AND ENTROPY MODULE
10001 IF TEMPP > -100 THEN GOTO 10010
10002 PRESS=PAMB
10003 GOTO 10480
10010 SWITCH1=0
10020 DIFFP=100000
10030 A=1
10040 B=13
10050 REM    B= 8
10060 IF V(A,B) =< VOL THEN GOTO 10080
10070 GOTO 10090
10080 IF V(A,B+1) > VOL THEN GOTO 10180
10090 B=B-1
10100 IF B <= 0 THEN GOTO 10120
10110 GOTO 10060
10120 B=13
10130 REM    B= 8
10140 A=A+1
10150 IF A >= 45 THEN GOTO 10300
10160 REM    IF A >=  9 THEN GOTO 10140
10170 GOTO 10060
10180 IF S(A,B) =< ENT THEN GOTO 10200
10190 GOTO 10090
10200 REM IF S(A-1,B+1) > ENT THEN GOTO 10071
10210 REM GOTO 10020
10220 DIFF=ABS((VOL-V(A,B))/(V(A,B+1)-V(A,B))-(ENT-S(A,B))/(S(A,B+1)-S(A,B)))
10230 IF DIFF < DIFFP THEN GOTO 10250
10240 GOTO 10090
```

```
10250 DIFFP=DIFF
10260 AA=A
10270 BB=B
10280 SWITCH1=1
10290 GOTO 10090
10300 IF SWITCH1 = 0 THEN GOTO 10460
10310 A=AA
10320 B=BB
10330 C=A+1
10340 D=B+1
10350 TV1=T(B)+((VOL-V(A,B))*(T(B+1)-T(B))/(V(A,B+1)-V(A,B)))
10360 TV2=T(D)+((VOL-V(C,D))*(T(D+1)-T(D))/(V(C,D+1)-V(C,D)))
10370 TS1=T(B)+((ENT-S(A,B))*(T(B+1)-T(B))/(S(A,B+1)-S(A,B)))
10380 TS2=T(D)+((ENT-S(C,D))*(T(D+1)-T(D))/(S(C,D+1)-S(C,D)))
10390 MV=(TV2-TV1)/(P(C)-P(A))
10400 BV=TV1-(MV*P(A))
10410 MS=(TS2-TS1)/(P(C)-P(A))
10420 BSS=TS1-(MS*P(A))
10430 TEMP=(BV-((MV*BSS)/MS))/(1-(MV/MS))
10440 PRESS=(TEMP-BSS)/MS
10450 GOTO 10470
10460 PRINT "DATA POINT OUT OF RANGE, VOL = ";VOL,"ENT = ";ENT
10461 GOTO 10002
10470 PRESS=PRESS*100
10480 PRESSP=PRESS
10481 VOLP=VOL
10482 IF TEMP < TEMPP THEN TEMPP=TEMP
10483 ENTP=ENT
10484 ALAST=A
10485 BLAST=B
10486 RETURN
11000 rem DATA BASED ON TEMPERATURE AND SPECIFIC VOLUME MODULE
11005 B=14
11015 A=1
11020 IF T(B) < TEMP THEN GOTO 11040
11025 B=B-1
11030 IF B <= 0 THEN GOTO 11160
11035 GOTO 11020
11040 IF V(A,B) < VOL THEN GOTO 11065
11045 A=A+1
11050 IF A > 45 THEN GOTO 11160
11060 GOTO 11040
11065 C=A+1
11070 D=B+1
11075 TV1=T(B)+((VOL-V(A,B))*(T(B+1)-T(B))/(V(A,B+1)-V(A,B)))
11080 TV2=T(D)+((VOL-V(C,D))*(T(D+1)-T(D))/(V(C,D+1)-V(C,D)))
11085 MV=(TV2-TV1)/(P(C)-P(A))
11090 BV=TV1-(MV*P(A))
11095 PRESS=(TEMP-BV)/MV
11100 PH=P(A+1)
11105 PL=P(A)
11110 TH=T(B+1)
11115 TL=T(B)
11120 S1L=S(A,B)
11125 S1H=S(A,B+1)
11130 S2L=S(A+1,B)
11135 S2H=S(A+1,B+1)
11140 SL=S1L-(ABS(PRESS-PL)/ABS(PH-PL))*(ABS(S2L-S1L))
11145 SH=S1H-(ABS(PRESS-PL)/ABS(PH-PL))*(ABS(S2H-S1H))
11150 ENT=SL+(ABS(TEMP-TL)/ABS(TH-TL))*ABS(SH-SL)
11155 GOTO 11165
11160 PRINT "DATA POINT OUT OF RANGE, TEMP = ";TEMP,"VOL = ";VOL
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```
11165 PRESS=PRESS*100
11170 RETURN
12000 rem STATIC ANALYSIS MODULE
12001 TEMPP=0
12002 rem
12004 IF DATAOUT$ <> "NONE" THEN GOSUB 13000
12006 FLAG1    = 0
12007 ALAST=1
12008 BLAST=13
12010 FLAG2    = 0
12011 MATCHTOT = 0
12012 MATCHMAX = 0
12015 PSTOPMAX = PSTART/GAIN
12020 rem SINCE THERE ARE 2 CYLINDERS, MULTIPLY THE AREA BY 2:
12025 AREA2 = 2.0  *  PI * ((PISDIA^2/4.0) - (RODDIA^2/4.0))
12030 AREA3 = 2.0  *  PI * PISDIA^2/4.0
12035 OMEGA = 0
12040 PRINT "THETA","TGRAV","TEQUIL","TELEV","PRESS","TEQUILA"
12042 PRINT " "
12044 IF DATAOUT$ <> "NONE" THEN PRINT #5; "THETA","TGRAV","TEQUIL","TELEV","
12045 IF DATAOUT$ <> "NONE" THEN PRINT #5; " "
12050 rem
12055 OPEN "STATIC.GRL" FOR OUTPUT AS FILE #2
12065 PRINT #2,"TITLE STATIC ANALYSIS RESULTS - Nitrogen"
12070 TIMENOW$ = TIME$(0)
12075 PRINT #2,"SUBTITLE ";DRIVER$;"    ";TODAY$;"  ";TIMENOW$
12080 PRINT #2,"HORIZONTAL_LABEL THETA (degrees)"
12085 PRINT #2,"VERTICAL_LABEL TORQUE (ft-lb)"
12090 PRINT #2,"Y_LEGEND gravity"
12095 PRINT #2,"Y_LEGEND equilibration"
12100 PRINT #2,"Y_LEGEND elevation"
12101 PRINT #2,"Y_LEGEND dyn equil"
12105 PRINT #2,""
12110 PRINT #2, "C THETA";"   TGRAV";"     TEQUIL";"     TELEV";"     DYNELEV
12115 rem GO TO INITIAL GAS & GEOMETRIC DATA MODULE:
12120 GOSUB 7000
12125 THETA = -5.0 * DEG_TO_RAD
12130 GOSUB 4000
12135 VOL   = (VE - ((DEQ-DF) * AREA1) - VCOMP) / MOLE
12136 ENT=ENTO
12137 GOSUB 10000
12138 TEQUILA=(PRESS-PAMB)*AREA1*RP
12139 P1=PRESS
12140 T1=TEMP
12141 V1=VOL
12142 S1=ENT
12143 TEMP  = TAMB
12145 GOSUB 11000
12150 TEQUIL= (PRESS-PAMB)*AREA1*RP
12155 rem FOR ELEVATING ONLY:
12160 VOLUME = ABS(GELI - GEL) * AREA2
12165 rem ASSUME STATIC ANALYSIS IS ISOTHERMAL:
12170 PCYL = (PAI * VAI) / (VAI + VOLUME)
12175 TELEV= (PCYL-PAMB) * AREA2 * RPE
12176 MATCH=ABS(TGRAV-TEQUIL)
12177 MATCHTOT=MATCHTOT+MATCH
12178 IF MATCH > MATCHMAX THEN MATCHMAX=MATCH
12180 PRINT THETA*RAD_TO_DEG,TGRAV/12.0,TEQUIL/12.0,TELEV/12.0,PRESS-PAMB,TEQ
12182 IF DATAOUT$ <> "NONE" THEN PRINT #5; THETA*RAD_TO_DEG,TGRAV/12.0,TEQUIL
12183 rem
12185 PRINT #2 USING "####.##",THETA*RAD_TO_DEG;
12190 PRINT #2,"  ";
```

```
12195 PRINT #2 USING "#######.#-",TGRAV/12.0;
12200 PRINT #2 USING "#######.#-",TEQUIL/12.0;
12205 PRINT #2 USING "#######.#-",TELEV/12.0;
12206 PRINT #2 USING "#######.#-",TEQUILA/12.0
12207 rem
12215 IF THETA >= 72.0 * DEG_TO_RAD  THEN GOTO 12230
12220 THETA = THETA +  1.0 * DEG_TO_RAD
12225 GOTO 12130
12230 CLOSE #2, #5
12231 PRINT "AVERAGE EQUILIBRATION MISMATCH = ";MATCHTOT/(78*12)
12232 PRINT "MAXIMUM EQUILIBRATION MISMATCH = ";MATCHMAX/12
12233 PRINT "ELEVATION CYLINDER STROKE = ";ABS(GELF-GELO)
12240 RETURN
13000 rem WRITING DESIGN PARAMETERS TO OUTPUT FILE DATAOUT$:
13005 rem Module added 3 November 1986. LKLP
13010 rem
13015 OPEN DATAOUT$ FOR OUTPUT AS FILE #5
13020 IF OPT1 = 4 THEN PRINT #5;"DYNAMIC ANALYSIS"
13025 IF OPT1 = 5 THEN PRINT #5;"STATIC ANALYSIS"
13030 rem
13035 TIMENOW$ = TIME$(0)
13040 PRINT #5; DRIVER$;" ELEVATION     :     ";TODAY$;"    ";TIMENOW$
13045 PRINT #5; " "
13050 PRINT #5; "EQUILIBRATION CYLINDER PARAMETERS: "
13055 PRINT #5; "---------------------------------"
13060 PRINT #5; "PISTON AREA                                IN^2    ";
13063 PRINT #5 USING "######.##", AREA1
13065 PRINT #5; "EQULIBRATOR VOLUME                         IN^3    ";
13067 PRINT #5 USING "######.##", VE
13070 PRINT #5; "AMBIENT TEMPERATURE                        deg-F   ";
13072 PRINT #5 USING "######.##", TAMB
13075 PRINT #5; "AMBIENT PRESSURE                           LB/IN^2 ";
13077 PRINT #5 USING "######.##", PAMB
13080 PRINT #5; "STARTING PRESSURE AT 0 Q.E.                LB/IN^2 ";
13082 PRINT #5 USING "######.##", PO-PAMB
13085 PRINT #5; "CHARGE PRESSURE AT 72 deg-F & 14.7 PSI     LB/IN^2 ";
13087 PRINT #5 USING "######.##", PCHARGE-14.7
13090 PRINT #5; "X LOCATION OF WIRE ROPE                    INCH    ";
13092 PRINT #5 USING "######.##", X
13095 PRINT #5; "Y LOCATION OF WIRE ROPE                    INCH    ";
13097 PRINT #5 USING "######.##", Y
13100 PRINT #5; " "
13105 PRINT #5; "ELEVATION CYLINDER PARAMETERS: "
13110 PRINT #5; "------------------------------"
13115 PRINT #5; "MAXIMUM MANUAL PRESSURE                    LB/IN^2 ";
13117 PRINT #5 USING "######.###", PCYLMAX-PAMB
13120 PRINT #5; "MAXIMUM MANUAL POWER INPUT                 HP      ";
13122 PRINT #5 USING "######.###", POWMAX;
13125 PRINT #5; "STARTING DECELERATION PRESS                LB/IN^2 ";
13127 PRINT #5 USING "######.###", PSTART-PAMB
13130 PRINT #5; "MAXIMUM DECELERATION TORQUE                FT-LB   ";
13132 PRINT #5 USING "######.###", TSTOPMAX/12.0
13135 PRINT #5; "ENERGY STORAGE ACCUMULATOR GAS VOLUME      IN^3    ";
13137 PRINT #5 USING "######.###", VAI
13140 PRINT #5; "ENERGY STORAGE ACCUMULATOR GAS PRESSURE    LB/IN^2 ";
13142 PRINT #5 USING "######.###", PAI-PAMB
13145 PRINT #5; "PISTON DIAMETER                            INCH    ";
13147 PRINT #5 USING "######.###", PISDIA
13150 PRINT #5; "ROD DIAMETER                               INCH    ";
13152 PRINT #5 USING "######.###", RODDIA
13155 PRINT #5; "GAIN VALUE                                         ";
13157 PRINT #5 USING "######.###", GAIN
```

```
13160 PRINT #5; " "
13165 PRINT #5; "SYSTEM PARAMETERS: "
13170 PRINT #5; "-----------------"
13175 PRINT #5; "STARTING ELEVATION (THETAo)                DEGREES   ";
13177 PRINT #5 USING "######.###", THETAO*180.0/PI
13180 PRINT #5; "ENDING ELEVATION   (THETAf)                DEGREES   ";
13182 PRINT #5 USING "######.###", THETAF*180.0/PI
13185 PRINT #5; "ELEVATING WEIGHT                           LBS       ";
13187 PRINT #5 USING "######.###", WT
13190 PRINT #5; "MASS MOMENT OF INERTIA (I)                 SLUG-FT^2 ";
13192 PRINT #5 USING "######.###", I
13195 PRINT #5; " "
13200 rem
13205 RETURN
14000 rem MODULE TO OPEN & INITIALIZE OUTPUT FILES:
14005 rem
14010 TIMENOW$ = TIME$(0)
14015 rem
14030 rem FILE FOR THETA -vs- TIME:
14035 OPEN "DYNTHETA.GRL" FOR OUTPUT AS FILE #6
14040 rem
14045 PRINT #6,"TITLE DYNAMIC ANALYSIS RESULTS - Nitrogen"
14050 PRINT #6,"SUBTITLE ";DRIVER$;"    ";TODAY$;"  ";TIMENOW$
14055 PRINT #6,"HORIZONTAL_LABEL TIME (seconds)"
14060 PRINT #6,"VERTICAL_LABEL THETA (degrees)"
14065 PRINT #6,"Y_LEGEND Elevation Angle"
14070 PRINT #6,""
14075 PRINT #6,"C TIME","ELEVATION"
14080 PRINT #6,"C (sec)","(degrees)"
14085 PRINT #6,""
14090 rem
14095 rem FILE FOR PCYL & PRESS -vs- TIME:
14100 OPEN "DYNPRESS.GRL" FOR OUTPUT AS FILE #7
14105 rem
14110 PRINT #7,"TITLE DYNAMIC ANALYSIS RESULTS - Nitrogen"
14115 PRINT #7,"SUBTITLE ";DRIVER$;"    ";TODAY$;"  ";TIMENOW$
14120 PRINT #7,"HORIZONTAL_LABEL TIME (seconds)"
14125 PRINT #7,"VERTICAL_LABEL PRESSURES (PSI)"
14130 PRINT #7,""
14135 PRINT #7,"Y_LEGEND PCYL  : Elev"
14140 PRINT #7,"Y_LEGEND PRESS : Equil"
14145 PRINT #7,""
14150 PRINT #7,"C     ", "ELEVATION","EQUILIBRATOR"
14155 PRINT #7,"C TIME", "PRESSURE", "PRESSURE"
14160 PRINT #7,"C (SEC)","(PSI)",    "(PSI)"
14165 PRINT #7,""
14170 rem
14175 rem FILE FOR FLOWRATE -vs- TIME:
14180 OPEN "DYNFLOW.GRL" FOR OUTPUT AS FILE #8
14185 rem
14190 PRINT #8,"TITLE DYNAMIC ANALYSIS RESULTS - Nitrogen"
14195 PRINT #8,"SUBTITLE ";DRIVER$;"    ";TODAY$;"  ";TIMENOW$
14200 PRINT #8,"HORIZONTAL_LABEL TIME (seconds)"
14205 PRINT #8,"VERTICAL_LABEL FLOWRATE (gal/min)"
14210 PRINT #8,""
14215 PRINT #8,"Y_LEGEND Elevation"
14220 PRINT #8,"Y_LEGEND Equilibration"
14225 PRINT #8,""
14230 PRINT #8,"C TIME", "FLOWELEV", "FLOWEQUIL"
14235 PRINT #8,"C (SEC)","(GPM)",    "(GPM)"
14240 PRINT #8,""
14245 rem
```

```
14250 RETURN
15000 REM OVERTURNNING TORQUE CALCULATION MODULE
15020 OTEQUIL=(TEQUIL/RP)*L3*SIN(BETA+LAMS)
15060 OTELEV=(TELEV/RPE)*L3E*SIN(BETAE+LAMES)
15070 FTX=(TEQUIL/RP)*COS(DELT-THETA)+(TELEV/RPE)*COS(DELTE-THETA)
15080 FTY=(TEQUIL/RP)*SIN(THETA-DELT)-(TELEV/RPE)*SIN(DELTE-THETA)+WT
15090 OTRUN=FTY*15-FTX*20
15100 OTGRAV=111485
15110 OVERTURN=OTGRAV+OTELEV+OTEQUIL+OTRUN
15900 RETURN
16000 END
```

37

when acceleration > 0

overturning torque = Torque $l_A \sin(\beta - \lambda_c)$

When acceleration < 0 then

overturning torque = $-$Torque $l_2 \sin(\beta + \lambda_c)$

$\alpha = \gamma - \theta$

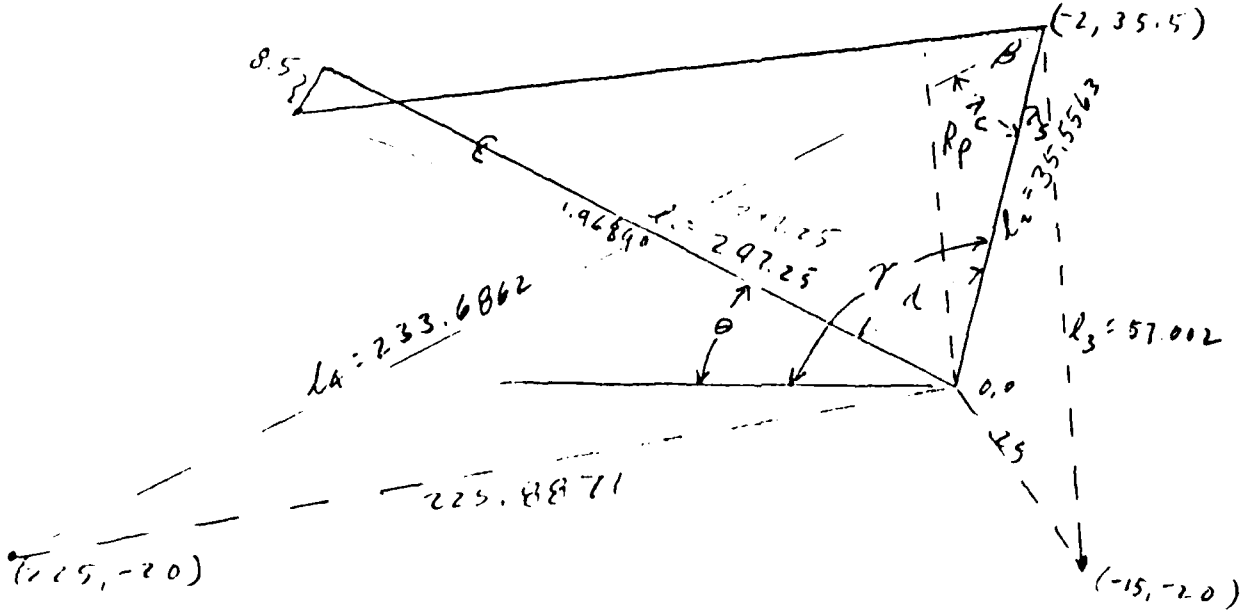
$D = \sqrt{l_1^2 + l_2^2 - 2 l_1 l_2 \cos\alpha}$

$\sin\beta = \frac{l_1 \sin\alpha}{D}$

$R_p = l_2 \sin\beta$

$\lambda_s = 16.4075$

$\lambda_c = 75.03,65$



36

claw

spade

38

when acceleration ≥ 0 then

overturning torque $= -F_{LEV} l_{1E} \sin(\lambda_1 - \beta)$

when acceleration < 0 then

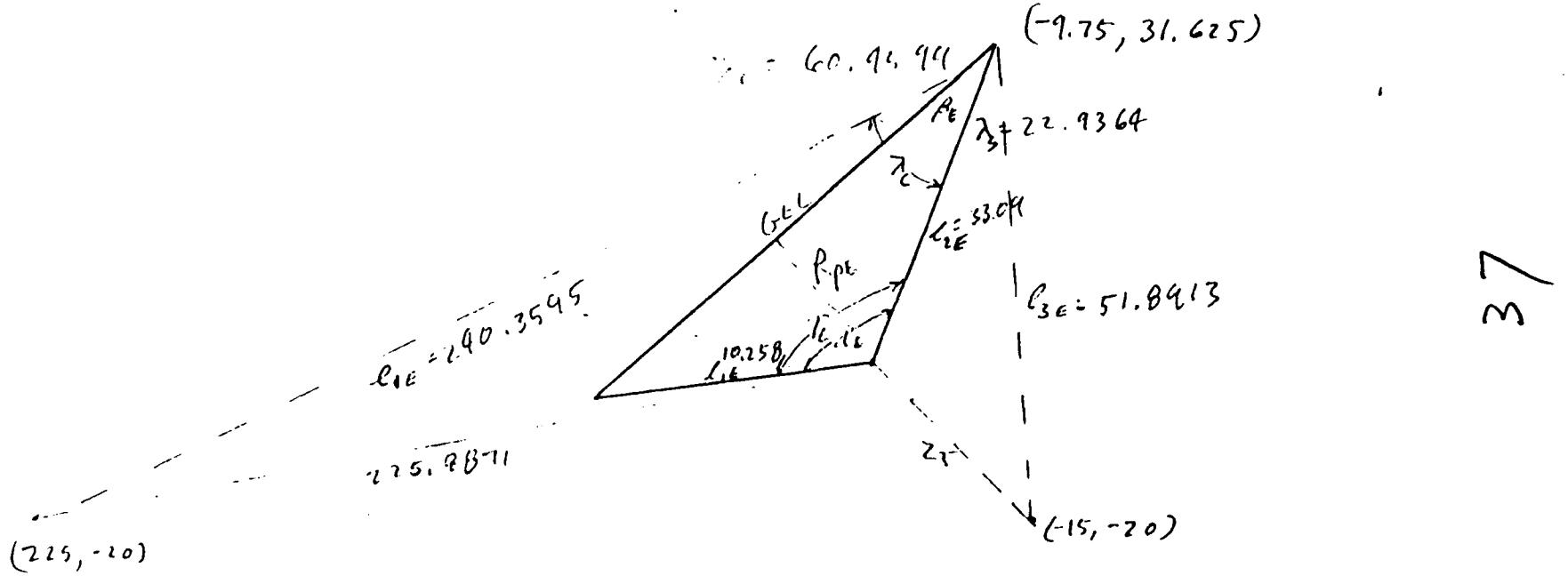
overturning torque $= F_{LEV} l_{2E} \sin(\beta + \lambda_3)$

$\alpha_E = \gamma_E - \theta$

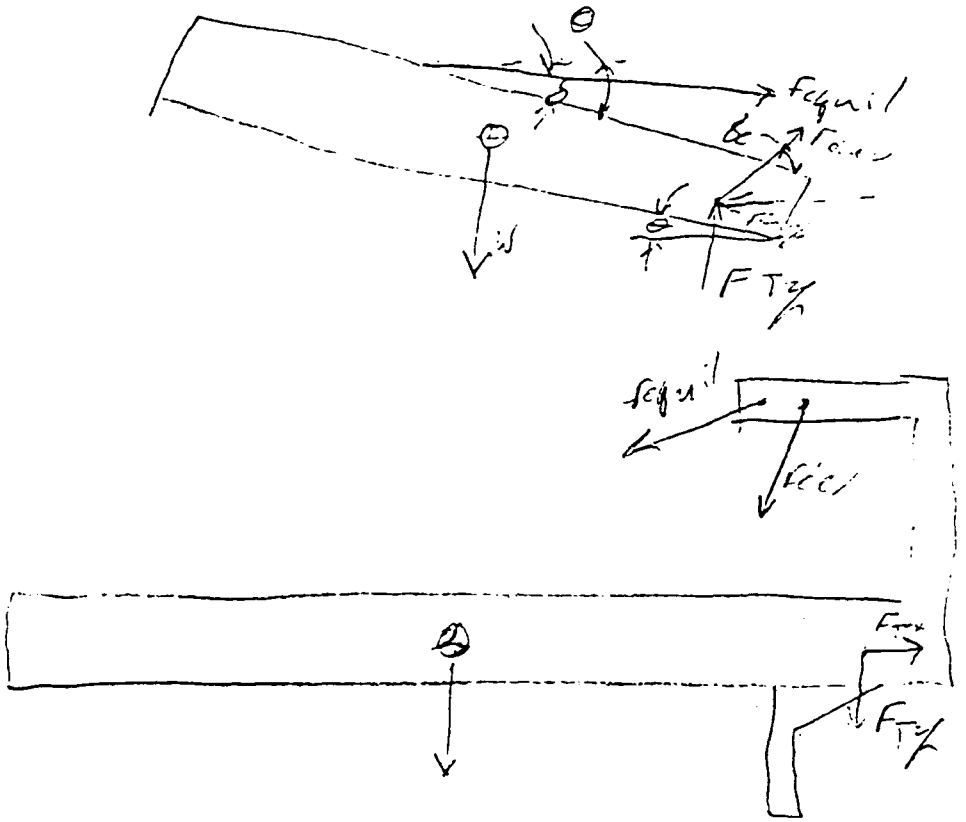
$GEL = \sqrt{l_{1E}^2 + l_{1E}^2 - 2 l_{1E} l_{1E} \cos \alpha_E}$

$\sin \beta_E = \frac{l_{1E} \sin \alpha_E}{GEL}$

$RP_E = l_{2E} \sin \beta_E$



37



$\delta = 180 - \alpha - \beta$

$\delta e = 180 - \alpha e - \beta e$

$F_{equil\,x} = F_{equil} \cos(\theta - \delta)$

$F_{equil\,y} = F_{equil} \sin(\theta - \delta)$

$F_{elevx} = F_{elev} \cos(\delta e - \theta)$

$F_{elevy} = F_{elev} \sin(\delta e - \theta)$

$F_{Tx} = F_{equil\,x} + F_{elev\,x}$

$F_{Ty} = W - F_{equil\,y} - F_{elev\,y}$

S. DACKO - 3/13/87
FOR J. GREEN

FINAL EQUILIBRATION & ELEVATION RESULTS

1. ACCUMULATOR VOLUME : 1200 CU. IN.
   CHARGE PRESS. = 2690 PSI
   CALIB PRESS. = 5414 PSI (0° QE)

2. EQUIL. PISTON DIA. = 3 1/8"
   ROD DIA. = 2 1/2"

3. ELEV. PISTON DIA. = 3"
   ROD DIA. = 1 1/2"

   MAX FLOW RATE : 14 GPM
   (VALVE W/ 3000 PSI ΔP AT 20 GPM)

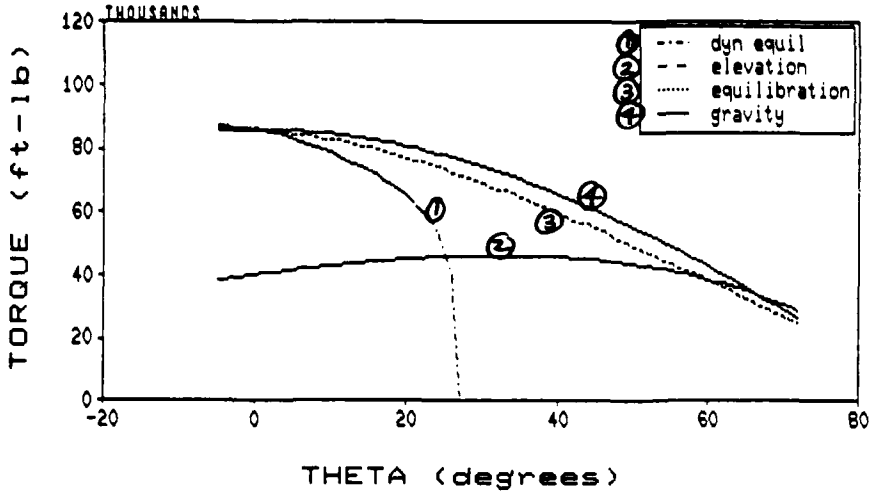
4. PEAK EQUIL PRESS = 6800 PSI (DEPR)
   NORMAL OP. PRESS = 5400 PSI (EQUIL)

5. OIL VOLUMES

T, °F	VOLUME, CU. IN.
−25	426.43
70	298.1
+160	179.4

STATIC ANALYSIS RESULTS - Nitrogen

ENERGY RECOVERY 05-Mar-87 11:12 AM



STATIC ANALYSIS
ENERGY RECOVERY ELEVATION : 05-Mar-87 11:12 AM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	-25.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	0.000
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

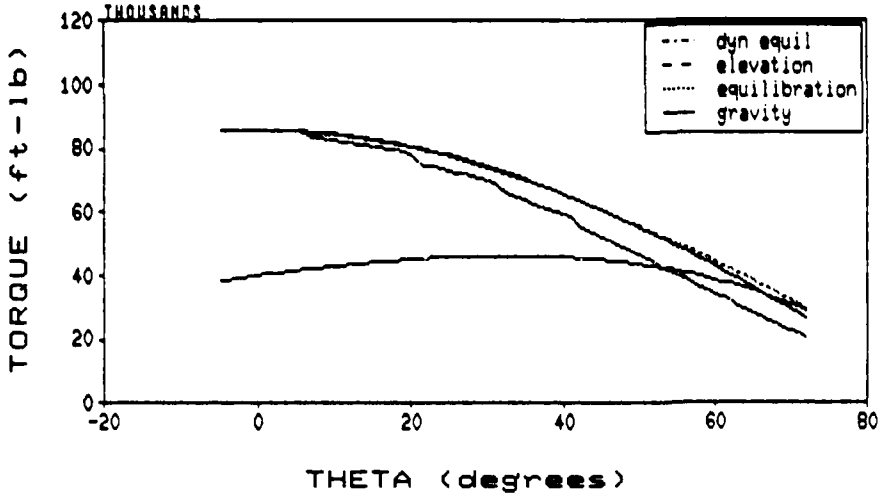
THETA	TGRAV	TEQUIL	TELEV	PRESS
-5	85740.5	86374.4	38449.8	5558.42
-4	85858.4	86349.6	38809.1	5527.17
-3	85950.1	86306.1	39162.7	5496.53

-2	86015.6	86244	39510.7	5466.48
-1	86054.9	86163.4	39852.7	5437.02
-.213443E-06	86068.1	86272.6	40188.7	5421.22
1	86054.9	85996.8	40518.5	5382.93
2	86015.6	85704.6	40841.8	5345.4
3	85950.1	85396.5	41158.6	5308.61
	85858.4	85072.4	41468.6	5272.56
	85740.5	84732.7	41771.7	5237.23
6	85596.6	84377.4	42067.6	5202.62
7	85426.5	84006.6	42356.2	5168.71
8	85230.4	83620.6	42637.2	5135.49
9	85008.4	83219.5	42910.4	5102.94
10	84760.5	82803.3	43175.6	5071.07
11	84486.7	82779.1	43432.6	5064.75
12	84187.3	82183.6	43681.2	5025.01
13	83862.1	81576.1	43921	4986.1
14	83511.5	80957	44152	4948
15	83135.4	80326.3	44373.7	4910.7
16	82733.9	79684.2	44585.9	4874.18
17	82307.3	79030.7	44788.4	4838.43
18	81855.6	78366.1	44980.9	4803.44
19	81378.9	77690.5	45163.1	4769.18
20	80877.5	77003.9	45334.6	4735.66
21	80351.5	76306.4	45495.3	4702.86
22	79800.9	76139.4	45644.7	4704.2
23	79226.1	75286.9	45782.5	4664.61
24	78627.1	74427.4	45908.5	4625.88
25	78004.1	73561	46022.2	4588
26	77357.5	72687.7	46123.3	4550.94
27	76687.2	71807.7	46211.4	4514.71
28	75993.6	70921.1	46286.2	4479.27
29	75276.8	70028.1	46347.2	4444.62
30	74537.1	69128.6	46394.2	4410.75
	73774.7	68222.8	46426.5	4377.63
32	72989.9	67310.8	46443.9	4345.27
33	72182.7	67050.6	46445.9	4356.39
34	71353.6	66013	46432.1	4310.37
35	70502.8	64973.2	46401.9	4281.22
36	69630.5	63931.3	46355	4244.93
37	68737	62887.3	46290.9	4209.49
38	67822.5	61841.5	46209	4174.89
39	66887.4	60793.8	46108.9	4141.11
40	65931.9	59744.3	45990.1	4108.13
41	64956.4	58693.1	45852	4075.96
42	63961	57640.2	45694.1	4044.56
43	62946.2	56585.6	45515.9	4013.94
44	61912.2	56308.8	45316.9	4039.99
45	60859.3	55159	45096.4	4004.86
46	59787.9	54011.5	44854	3970.61
47	58698.3	52866.4	44589	3937.25
48	57590.8	51723.8	44300.9	3904.76
49	56465.7	50583.5	43989.2	3873.11
50	55323.5	49445.6	43653.1	3842.31
51	54164.4	48310.2	43292.3	3812.34
52	52988.8	47177.2	42906	3783.19
53	51797	46046.6	42493.8	3754.84
54	50589.5	44918.4	42055.1	3727.3
55	49366.6	43792.7	41589.3	3700.54
56	48128.6	42669.3	41095.9	3674.56
57	46876	41548.3	40574.3	3649.34

58	45609.1	41108.9	40024.1	3685.79
59	44328.3	39929.7	39444.7	3657.65
60	43034	38756.1	38835.7	3630.39
61	41726.6	37588.1	38196.6	3603.99
62	40406.5	36425.5	37527.2	3578.46
63	39074	35268.3	36826.9	3553.78
	37729.7	34116.3	36095.4	3529.94
	36373.9	32969.4	35332.6	3506.94
66	35007	31827.6	34538.1	3484.76
67	33629.4	30690.7	33711.7	3463.4
68	32241.6	29558.6	32853.4	3442.85
69	30844	28431.2	31963.2	3423.1
70	29437	27308.3	31040.9	3404.15
71	28021	26189.8	30086.8	3385.98
72	26596.4	25075.5	29101	3368.6

STATIC ANALYSIS RESULTS - Nitrogen

ENERGY RECOVERY 05-Mar-87 11:13 AM



STATIC ANALYSIS
ENERGY RECOVERY ELEVATION : 05-Mar-87 11:13 AM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	70.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	0.000
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

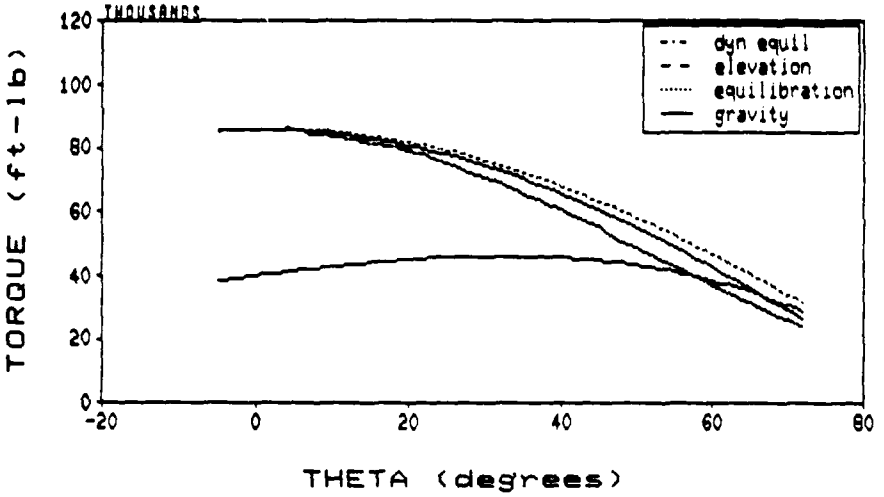
THETA	TGRAV	TEQUIL	TELEV	PRESS
-5	85740.5	85606.4	38449.8	5509
-4	85858.4	85743.1	38809.1	5488.35
-3	85950.1	85857.2	39162.7	5467.94

-2	86015.6	85948.7	39510.7	5447.77
-1	86054.9	86017.8	39852.7	5427.83
-.213443E-06	86068.1	86064.4	40188.7	5408.14
1	86054.9	86088.7	40518.5	5388.68
2	86015.6	86090.7	40841.8	5369.47
3	85950.1	86070.5	41158.6	5350.51
	85858.4	86028.1	41468.6	5331.79
	85740.5	85646	41771.7	5293.69
6	85596.6	85444.1	42067.6	5268.39
7	85426.5	85222.9	42356.2	5243.54
8	85230.4	84982.4	42637.2	5219.12
9	85008.4	84722.8	42910.4	5195.12
10	84760.5	84444.1	43175.6	5171.55
11	84486.7	84146.3	43432.6	5148.4
12	84187.3	83829.6	43681.2	5125.66
13	83862.1	83494.1	43921	5103.33
14	83511.5	83139.7	44152	5081.41
15	83135.4	82766.6	44373.7	5059.89
16	82733.9	82374.8	44585.9	5038.76
17	82307.3	81964.3	44788.4	5018.03
18	81855.6	81535.2	44980.9	4997.69
19	81378.9	81087.6	45163.1	4977.72
20	80877.5	80621.5	45334.6	4958.14
21	80351.5	80123.9	45495.3	4938.14
22	79800.9	79492.5	45644.7	4911.37
23	79226.1	78847.5	45782.5	4885.22
24	78627.1	78189	45908.5	4859.68
25	78004.1	77517	46022.2	4834.73
26	77357.5	76831.4	46123.3	4810.38
27	76687.2	76132.3	46211.4	4786.6
28	75993.6	75419.5	46286.2	4763.38
29	75276.8	74693.1	46347.2	4740.71
30	74537.1	73953.2	46394.2	4718.58
	73774.7	73199.6	46426.5	4696.98
32	72989.9	72432.3	46443.9	4675.89
33	72182.7	71651.4	46445.9	4655.32
34	71353.6	70856.9	46432.1	4635.24
35	70502.8	70048.6	46401.9	4615.65
36	69630.5	69226.8	46355	4596.54
37	68737	68786.3	46290.9	4604.35
38	67822.5	67810.6	46209	4577.86
39	66887.4	66828	46108.9	4552.14
40	65931.9	65838.1	45990.1	4527.16
41	64956.4	64841	45852	4502.9
42	63961	63836.4	45694.1	4479.34
43	62946.2	62824.1	45515.9	4456.48
44	61912.2	61804.3	45316.9	4434.28
45	60859.3	60776.6	45096.4	4412.73
46	59787.9	59741	44854	4391.82
47	58698.3	58697.5	44589	4371.52
48	57590.8	57646	44300.9	4351.84
49	56465.7	56586.4	43989.2	4332.75
50	55323.5	55518.7	43653.1	4314.24
51	54164.4	54442.8	43292.3	4296.29
52	52988.8	53358.7	42906	4278.89
53	51797	52266.5	42493.8	4262.04
54	50589.5	51166	42055.1	4245.72
55	49366.6	50057.3	41589.3	4229.91
56	48128.6	48940.5	41095.9	4214.61
57	46876	48364.2	40574.3	4248.01

58	45609.1	47142.1	40024.1	4226.73
59	44328.3	45918.3	39444.7	4206.22
60	43034	44692.6	38835.7	4186.47
61	41726.6	43464.8	38196.6	4167.46
62	40406.5	42234.8	37527.2	4149.17
63	39074	41002.5	36826.9	4131.59
64	37729.7	39767.7	36095.4	4114.69
	36373.9	38530.5	35332.6	4098.46
66	35007	37290.6	34538.1	4082.89
67	33629.4	36048.1	33711.7	4067.97
68	32241.6	34802.8	32853.4	4053.67
69	30844	33554.9	31963.2	4039.99
70	29437	32304.1	31040.9	4026.91
71	28021	31050.6	30086.8	4014.43
72	26596.4	29794.4	29101	4002.53

STATIC ANALYSIS RESULTS - Nitrogen

ENERGY RECOVERY 05-Mar-87 11:13 AM



STATIC ANALYSIS
ENERGY RECOVERY ELEVATION : 05-Mar-87 11:13 AM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	160.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	0.000
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

THETA	TGRAV	TEQUIL	TELEV	PRESS
-5	85740.5	85325.7	38449.8	5490.93
-4	85858.4	85524.9	38809.1	5474.38
-3	85950.1	85700	39162.7	5457.93

-2	86015.6	85851	39510.7	5441.57
-1	86054.9	85977.9	39852.7	5425.32
-.213443E-06	86068.1	86080.8	40188.7	5409.17
1	86054.9	86159.7	40518.5	5393.13
2	86015.6	86214.6	40841.8	5377.2
3	85950.1	86245.5	41158.6	5361.39
4	85858.4	86252.6	41468.6	5345.7
5	85740.5	86235.7	41771.7	5330.13
6	85596.6	86195	42067.6	5314.69
7	85426.5	86130.5	42356.2	5299.38
8	85230.4	86042.2	42637.2	5284.2
9	85008.4	85930.1	42910.4	5269.16
10	84760.5	85255.9	43175.6	5221.27
11	84486.7	85027.8	43432.6	5202.33
12	84187.3	84776.9	43681.2	5183.58
13	83862.1	84503.1	43921	5165.01
14	83511.5	84206.7	44152	5146.62
15	83135.4	83887.8	44373.7	5128.43
16	82733.9	83546.4	44585.9	5110.43
17	82307.3	83182.8	44788.4	5092.63
18	81855.6	82797	44980.9	5075.02
19	81378.9	82389.1	45163.1	5057.62
20	80877.5	81959.3	45334.6	5040.42
21	80351.5	81507.6	45495.3	5023.42
22	79800.9	81034.3	45644.7	5006.63
23	79226.1	80539.4	45782.5	4990.04
24	78627.1	80023	45908.5	4973.67
25	78004.1	79485.4	46022.2	4957.5
26	77357.5	78926.5	46123.3	4941.55
27	76687.2	78346.5	46211.4	4925.82
28	75993.6	77745.6	46286.2	4910.29
29	75276.8	77123.9	46347.2	4894.99
30	74537.1	76481.6	46394.2	4879.9
31	73774.7	75465.1	46426.5	4842.35
32	72989.9	74727.8	46443.9	4824.08
33	72182.7	73971.9	46445.9	4806.08
34	71353.6	73197.6	46432.1	4788.37
35	70502.8	72405.1	46401.9	4770.93
36	69630.5	71594.6	46355	4753.76
37	68737	70766.3	46290.9	4736.88
38	67822.5	69920.3	46209	4720.28
39	66887.4	69056.8	46108.9	4703.96
40	65931.9	68176.2	45990.1	4687.92
41	64956.4	67278.4	45852	4672.17
42	63961	66363.8	45694.1	4656.7
43	62946.2	65432.6	45515.9	4641.51
44	61912.2	64484.9	45316.9	4626.6
45	60859.3	63521	45096.4	4611.99
46	59787.9	62541	44854	4597.65
47	58698.3	61545.2	44589	4583.6
48	57590.8	60533.8	44300.9	4569.84
49	56465.7	59506.9	43989.2	4556.37
50	55323.5	58464.9	43653.1	4543.18
51	54164.4	57408	43292.3	4530.28
52	52988.8	56336.3	42906	4517.67
53	51797	55250.2	42493.8	4505.34
54	50589.5	54149.8	42055.1	4493.3
55	49366.6	53035.3	41589.3	4481.55
56	48128.6	51722.1	41095.9	4454.16
57	46876	50556	40574.3	4440.52

58	45609.1	49378.5	40024.1	4427.24
59	44328.3	48190	39444.7	4414.31
60	43034	46990.6	38835.7	4401.73
61	41726.6	45780.6	38196.6	4389.51
62	40406.5	44560.3	37527.2	4377.64
63	39074	43330	36826.9	4366.11
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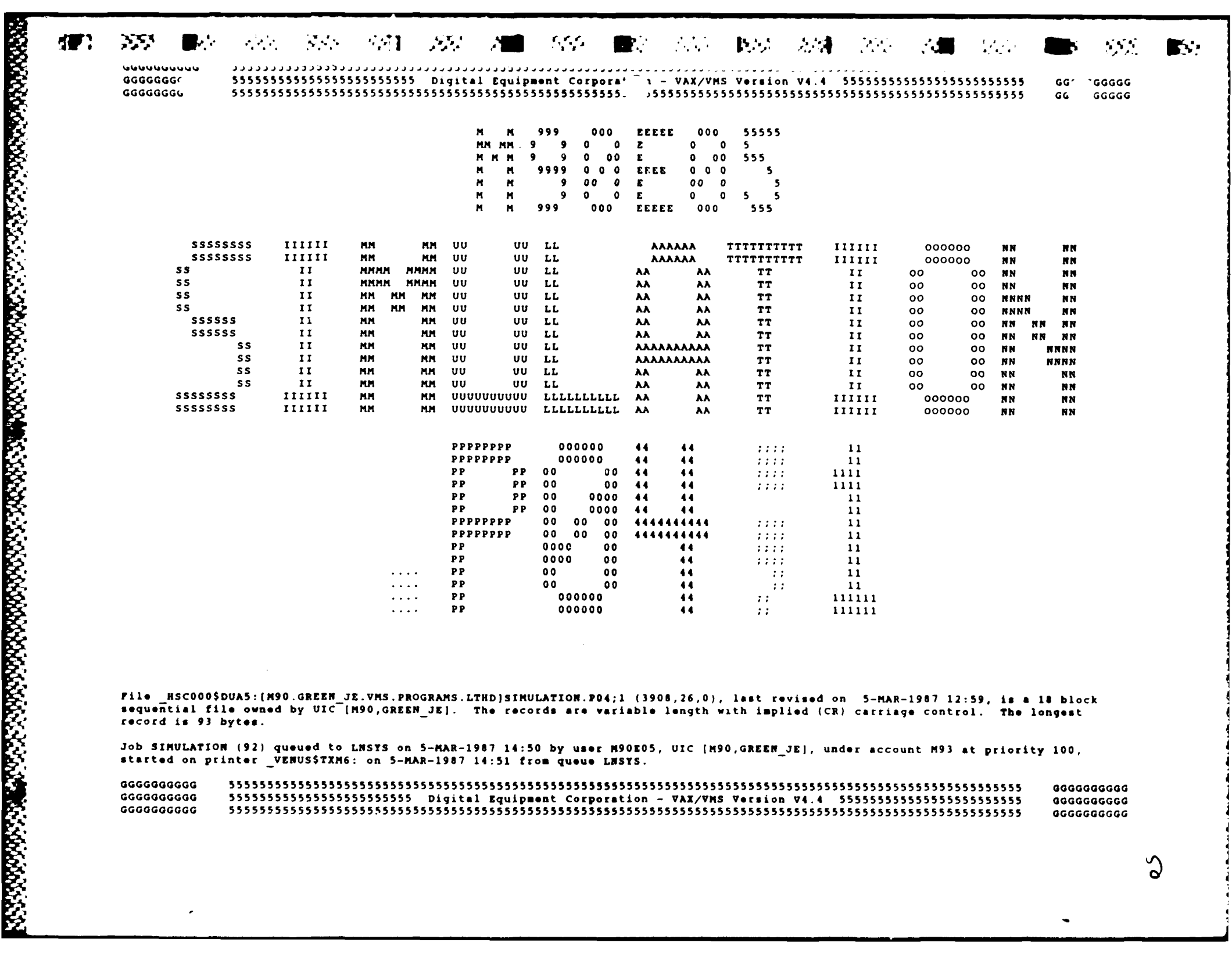
	36373.9	40840	35332.6	4344.13
66	35007	39581	34538.1	4333.67
67	33629.4	38312.9	33711.7	4323.55
68	32241.6	37036.1	32853.4	4313.79
69	30844	35750.9	31963.2	4304.39
70	29437	34457.4	31040.9	4295.33
71	28021	33156	30086.8	4286.63
72	26596.4	31847	29101	4278.28


Digital Equipment Corporation - VAX/VMS Version V4.4
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Job SIMULATION (92) queued to LNSYS on 5-MAR-1987 14:50 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:51 from queue LNSYS.

DYNAMIC ANALYSIS
ENERGY RECOVERY ELEVATION : 05-Mar-87 12:57 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	-25.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	33.750
ENDING ELEVATION (THETAf)	DEGREES	45.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.049	33.7994	2943.12	4251.72	2.73935	1.61458	1.93884
.099	33.94	2796.95	4239.88	5.17463	3.02491	3.63598
.149	34.1578	2604.26	4222.68	7.22182	4.16859	5.0184
.199	34.4362	2405.37	4202.32	8.84889	5.02698	6.06385
.249	34.7589	2228	4180.5	10.0777	5.6219	6.79743
.299	35.1116	2085.31	4158.35	10.963	5.99767	7.27077
.348999	35.4827	1979.33	4136.48	11.5728	6.20507	7.54334
.398998	35.8635	1905.78	4115.19	11.9734	6.29108	7.67044
.448998	36.248	1857.94	4094.57	12.2221	6.2942	7.69755
.498997	36.6322	1829.09	4074.65	12.3645	6.24353	7.65925
.548997	37.0133	1813.52	4055.4	12.4347	6.15989	7.58035
.598996	37.3899	1806.86	4036.78	12.4573	6.05753	7.47796
.648995	37.761	1805.96	4018.75	12.4495	5.94584	7.36341
.698995	38.1263	1808.61	4001.28	12.423	5.83084	7.24401
.748994	38.4855	1813.33	3984.34	12.3855	5.71623	7.1243
.798993	38.8385	1828.99	3892.73	12.2893	5.5803	6.9771
.848993	39.1831	1853.49	3868.69	12.1444	5.42896	6.80941
.898992	39.5199	1873.5	3845.45	12.0229	5.29434	6.6615
.948991	39.8496	1890.39	3822.95	11.9178	5.17236	6.52846
.998991	40.173	1905.05	3801.15	11.8245	5.06027	6.40696
1.04899	40.4906	1918.08	3780.01	11.7399	4.95617	6.29474
1.099	40.8028	1929.86	3759.47	11.6621	4.85874	6.1902
1.149	41.1098	1940.66	3739.51	11.5895	4.76701	6.09221
1.199	41.4122	1950.66	3720.08	11.5214	4.68026	5.99992
1.249	41.71	1959.99	3701.18	11.4569	4.59794	5.91267

1.299	42.0036	1968.73	3682.76	11.3956	4.51962	5.82998
1.349	42.2931	1976.96	3664.8	11.3371	4.44494	5.75141
1.3990.	42.5789	1984.73	3647.28	11.2812	4.37359	5.67664
1.44901	42.8609	1992.08	3630.18	11.2277	4.30534	5.60537
1.49901	43.1395	1999.05	3613.48	11.1763	4.23994	5.53736
1.54902	43.4148	2005.67	3597.16	11.1269	4.17721	5.47237
1.59902	43.6869	2011.95	3581.21	11.0795	4.11698	5.41021
1.64902	43.9553	2032.31	3482.82	10.947	4.02725	5.30871
1.69902	44.2179	2055.76	3459.06	10.7942	3.93271	5.20001
1.74903	44.4756	2074.19	3436.01	10.6706	3.85124	5.10781
1.79903	44.729	2089.4	3413.61	10.566	3.77866	5.02675
1.84903	44.9785	2102.48	3391.8	10.4741	3.71239	4.95351

PRESSURE AFTER EXTENDED TIME = 4019.44
ELEVATION CYLINDER STROKE = 8.07513
TEMPERATURE COMPENSATION VOLUME = 426.434

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
1.89903	44.92	2257.61	3904.78	9.43499	-2.51333	-3.3512
1.94904	44.6957	1253.66	3924.19	14.8993	-4.00105	-5.32047
1.99904	44.4096	834.608	4009.89	16.6519	-4.51835	-5.9879
2.04903	44.1039	712.245	4023.9	17.1229	-4.69857	-6.20437
2.09903	43 7912	680.691	4037.87	17.2351	-4.78455	-6.29502
2.14903	43.475	675.534	4052.02	17.2452	-4.84453	-6.35092
2.19902	43.1563	677.957	4066.42	17.226	-4.89813	-6.39815
2.24902	42.8352	682.656	4081.08	17.198	-4.95094	-6.4441
2.29902	42.5119	688.149	4096.02	17.1667	-5.00462	-6.49093
2.34901	42.1862	694.022	4111.27	17.1339	-5.05967	-6.53932
2.39901	41.858	700.164	4126.81	17.0999	-5.11632	-6.58952
2.449	41.5272	706.554	4142.68	17.0647	-5.17469	-6.64167
2.499	41.1938	713.187	4158.87	17.0285	-5.23488	-6.69588
2.549	40.8577	720.08	4175.41	16.9911	-5.297	-6.75228
2.59899	40.5186	727.235	4192.31	16.9525	-5.36115	-6.81098
2.64899	40.1766	734.676	4209.59	16.9125	-5.42745	-6.8721
2.69899	39.8314	742.412	4227.25	16.8713	-5.49603	-6.93578
2.74898	39.483	750.459	4245.32	16.8286	-5.56702	-7.00217
2.79898	39.1312	758.839	4263.81	16.7844	-5.64057	-7.07143
2.84898	38.7759	767.564	4282.75	16.7386	-5.71684	-7.14374
2.89897	38.4169	776.66	4302.16	16.691	-5.796	-7.21928
2.94897	38.054	786.154	4322.05	16.6417	-5.87825	-7.29827
2.99897	37.6871	796.065	4342.46	16.5903	-5.9638	-7.38094
3.04896	37.3159	806.421	4363.41	16.537	-6.05287	-7.46753
3.09896	36.9403	817.259	4384.92	16.4813	-6.1457	-7.55832
3.14895	36.5601	828.606	4407.03	16.4233	-6.24259	-7.65362
3.19895	36.175	840.501	4429.77	16.3627	-6.34384	-7.75376
3.24895	35.7847	852.991	4453.18	16.2994	-6.44978	-7.85911
3.29894	35.3891	866.12	4477.3	16.2329	-6.56079	-7.97009
3.34894	34.9877	879.938	4502.17	16.1632	-6.67728	-8.08715
3.39894	34.5804	894.51	4527.83	16.09	-6.79972	-8.21081
3.44893	34.1669	912.753	4559.27	16.0009	-6.92342	-8.33538
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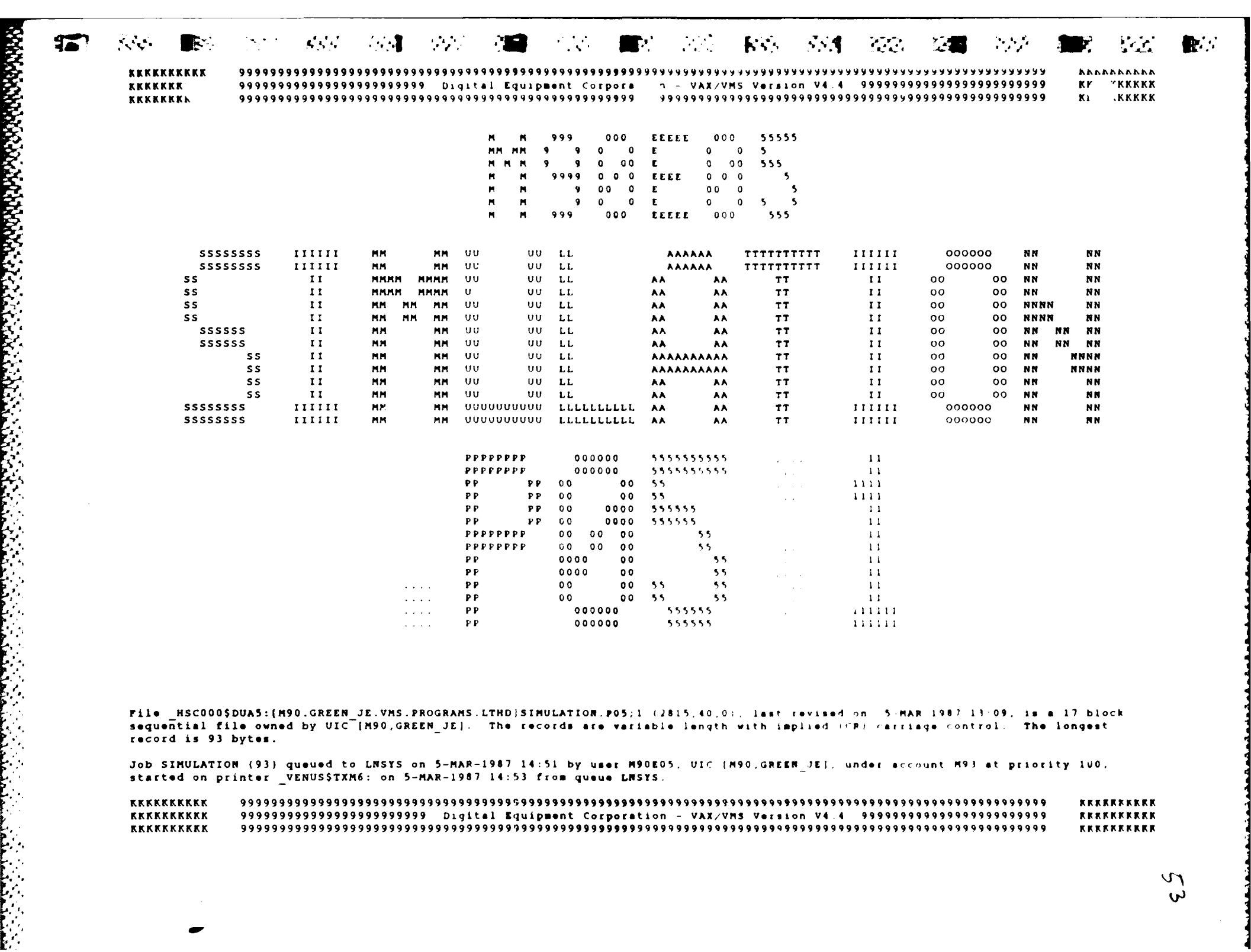

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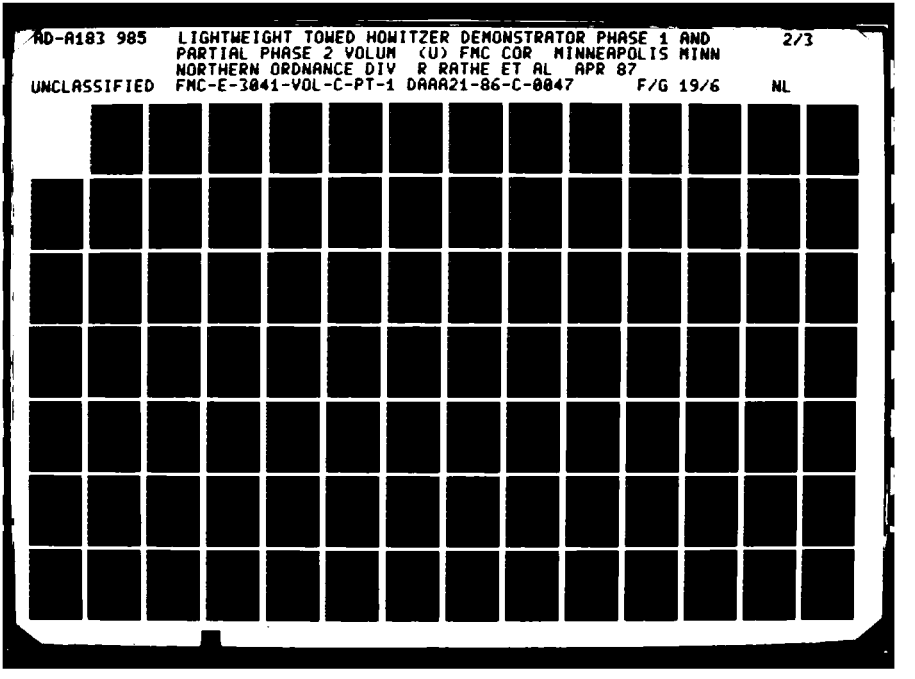
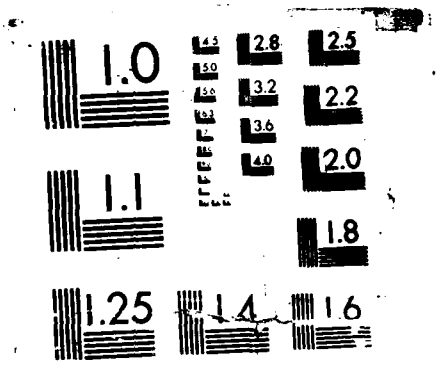
Job SIMULATION (93) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:53 from queue LNSYS.


AD-A183 985 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND 2/3
PARTIAL PHASE 2 VOLUM (U) FMC COR MINNEAPOLIS MINN
NORTHERN ORDNANCE DIV R RATHE ET AL APR 87
UNCLASSIFIED FMC-E-3041-VOL-C-PT-1 DAAA21-86-C-0047 F/G 19/6 NL



MICROCOPY RESOLUTION TEST CHART

ENERGY RECOVERY ELEVATION : 05-Mar-87 01:07 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	70.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	33.750
ENDING ELEVATION (THETAf)	DEGREES	45.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.049	33.8095	2917.64	4632.43	3.29793	1.94266	2.33298
.099	33.9781	2708.8	4622.76	6.19999	3.61625	4.34794
.149	34.2373	2440.79	4609.63	8.5893	4.93529	5.94476
.199	34.5653	2174	4595.33	10.4351	5.88492	7.10539
.249	34.9413	1945.82	4581.33	11.7831	6.50706	7.87827
.299	35.3479	1770.09	4568.25	12.7204	6.87012	8.34326
.348999	35.7719	1644.87	4556.23	13.3439	7.04515	8.58372
.398998	36.2038	1560.93	4545.14	13.7414	7.09283	8.67119
.448998	36.6374	1507.49	4534.78	13.9838	7.05934	8.6604
.498997	37.0689	1475.12	4525	14.1235	6.97721	8.59011
.548997	37.4959	1456.59	4515.65	14.1975	6.86813	8.48628
.598996	37.9173	1446.78	4506.66	14.2308	6.74591	8.36555
.648995	38.3325	1442.25	4497.96	14.2396	6.61901	8.23819
.698995	38.7413	1440.78	4489.5	14.2344	6.49238	8.1103
.748994	39.1437	1440.99	4481.26	14.2215	6.3688	7.98532
.798993	39.54	1442.02	4473.22	14.2051	6.24968	7.86504
.848993	39.9304	1443.37	4465.37	14.1873	6.13563	7.75029
.898992	40.3153	1444.76	4457.69	14.1695	6.02682	7.64135
.948991	40.6948	1446.03	4450.18	14.1524	5.92314	7.53814
.998991	41.0693	1447.11	4442.83	14.1364	5.82438	7.44045
1.04899	41.439	1447.96	4435.62	14.1216	5.73023	7.34798
1.099	41.8042	1448.58	4428.56	14.108	5.64042	7.26041
1.149	42.1652	1448.96	4421.64	14.0958	5.55463	7.17742
1.199	42.5221	1449.13	4414.85	14.0846	5.47259	7.09868
1.249	42.8752	1449.09	4408.19	14.0746	5.39404	7.02393

1.299	43.2247	1448.86	4401.65	14.0656	5.31873	6.95489
1.3490:	43.5706	1448.46	4395.23	14.0576	5.24645	6.88532
1.39901	43.9116	1483.28	4255.55	13.8823	5.11541	6.7397
1.44901	44.2454	1509.75	4248.85	13.7455	5.00294	6.61726
1.49901	44.574	1523.96	4242.2	13.6671	4.91515	6.52651
1.54902	44.8984	1531.41	4235.62	13.6214	4.84175	6.45416

PRESSURE AFTER EXTENDED TIME = 4427.4
ELEVATION CYLINDER STROKE = 8.07513
TEMPERATURE COMPENSATION VOLUME = 298.095

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
1.59902	44.9589	2603.28	4450.3	6.5725	-1.74837	-2.33233
1.64902	44.7806	1708.81	4459.03	12.7157	-3.40423	-4.53147
1.69902	44.5276	1192.55	4467.59	15.1631	-4.09674	-5.43678
1.74903	44.2463	1004.77	4475.16	15.9541	-4.35496	-5.76025
1.79903	43.9548	946.36	4482.34	16.1856	-4.46593	-5.88695
1.84903	43.6587	929.754	4489.48	16.2438	-4.53179	-5.95339
1.89903	43.3598	926	4496.69	16.2494	-4.58475	-6.00252
1.94904	43.0585	926.203	4504.01	16.2387	-4.63471	-6.04745
1.99904	42.7551	927.677	4511.46	16.2227	-4.68472	-6.09221
2.04903	42.4493	929.616	4519.04	16.2047	-4.73577	-6.13808
2.09903	42.1413	931.775	4526.77	16.1857	-4.78821	-6.18551
2.14903	41.8308	934.085	4534.65	16.166	-4.84221	-6.23469
2.19902	41.5178	936.527	4542.68	16.1457	-4.89787	-6.28576
2.24902	41.2023	939.101	4550.87	16.1247	-4.9553	-6.33882
2.29902	40.884	941.812	4559.22	16.103	-5.01459	-6.39398
2.34901	40.5629	944.671	4567.75	16.0806	-5.07586	-6.45137
2.39901	40.2389	947.678	4576.46	16.0574	-5.13921	-6.51109
2.449	39.9118	950.848	4585.36	16.0334	-5.20477	-6.57329
2.499	39.5815	954.195	4594.46	16.0086	-5.27267	-6.63811
2.549	39.248	957.721	4603.76	15.9829	-5.34305	-6.7057
2.59899	38.911	961.445	4613.27	15.9562	-5.41607	-6.77624
2.64899	38.5704	965.378	4623.01	15.9284	-5.4919	-6.84992
2.69899	38.226	969.538	4632.99	15.8996	-5.57072	-6.92693
2.74898	37.8777	973.939	4643.21	15.8696	-5.65274	-7.0075
2.79898	37.5253	978.597	4653.7	15.8382	-5.73818	-7.09187
2.84898	37.1685	983.537	4664.46	15.8056	-5.82728	-7.18033
2.89897	36.8073	988.784	4675.51	15.7714	-5.92031	-7.27314
2.94897	36.4412	994.356	4686.87	15.7356	-6.01757	-7.37065
2.99897	36.0702	1000.3	4698.55	15.698	-6.11939	-7.47322
3.04896	35.6939	1006.62	4710.58	15.6585	-6.22612	-7.58124
3.09896	35.3121	1013.37	4722.97	15.617	-6.33818	-7.69516
3.14895	34.9244	1020.6	4735.75	15.5731	-6.45602	-7.8155
3.19895	34.5306	1028.35	4748.94	15.5267	-6.58015	-7.94279
3.24895	34.1302	1036.67	4762.58	15.4774	-6.71113	-8.07768

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   SS             II     MMMM   MMMM  UU       UU  LL           AA      AA      TT         II    OO      OO  NN      NN
   SS             II     MM  MM  MM   UU       UU  LL           AA      AA      TT         II    OO      OO  NNNN    NN
   SS             II     MM  MM  MM   UU       UU  LL           AA      AA      TT         II    OO      OO  NNNN    NN
     SSSSSS       II     MM       MM  UU       UU  LL           AA      AA      TT         II    OO      OO  NN  NN  NN
     SSSSSS       II     MM       MM  UU       UU  LL           AA      AA      TT         II    OO      OO  NN  NN  NN
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           SS     II     MM       MM  UU       UU  LL           AAAAAAAAAA      TT         II    OO      OO  NN    NNNN
           SS     II     MM       MM  UU       UU  LL           AA      AA      TT         II    OO      OO  NN      NN
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File _NSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]SIMULATION.P06;1 (1633,14,0), last revised on 5-MAR-1987 13:11, is a 17 block sequential file owned by UIC [M90,GREEN_JE]. The records are variable length with implied (CR) carriage control. The longest record is 93 bytes.

Job SIMULATION (94) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:53 from queue LNSYS.

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95

DYNAMIC ANALYSIS
ENERGY * *OVERY ELEVATION : 05-Mar-87 01:09 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	160.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	33.750
ENDING ELEVATION (THETAf)	DEGREES	45.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

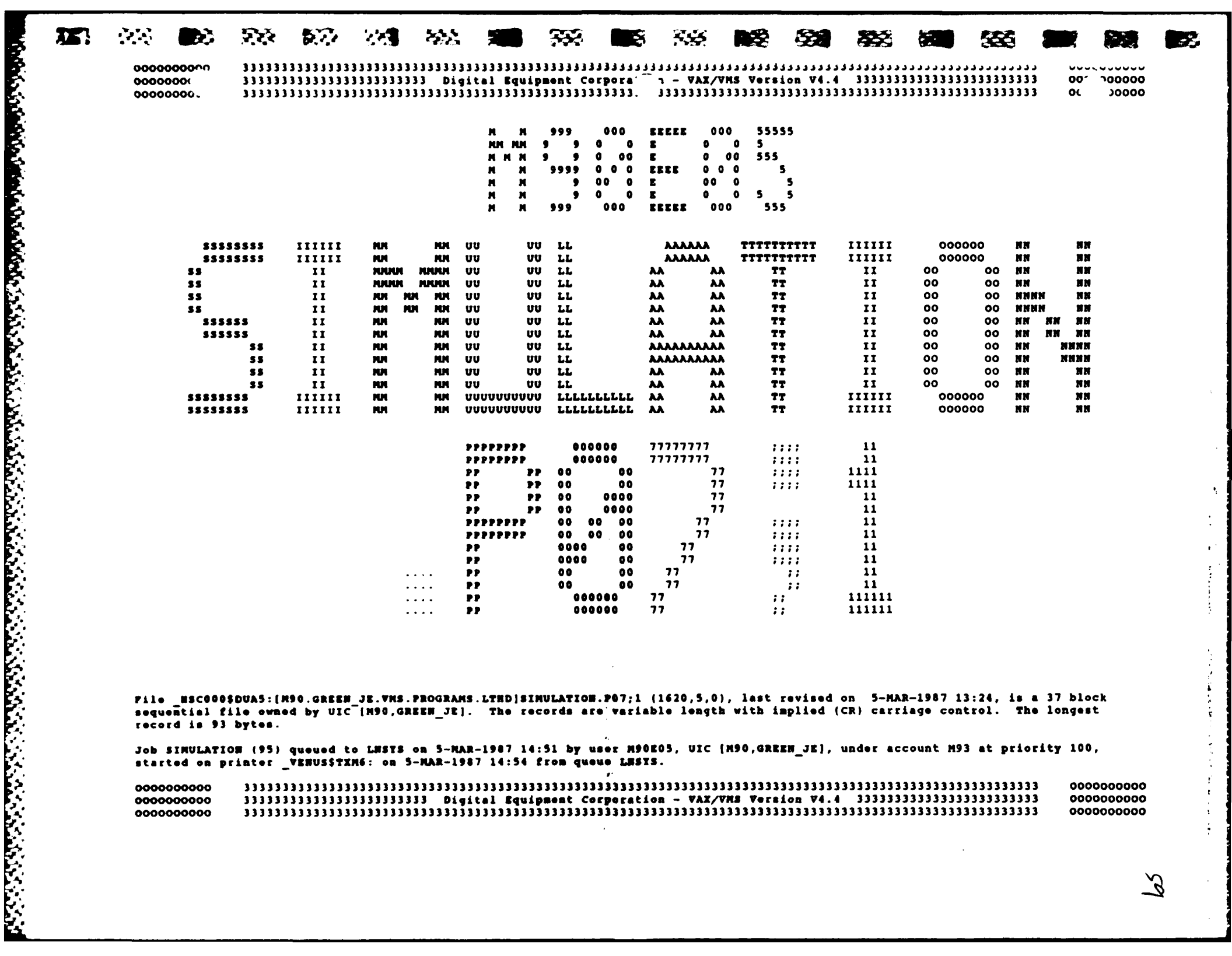
TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.049	33.8136	2905.86	4788.16	3.52647	2.07678	2.49412
.099	33.9936	2668.72	4777.27	6.61391	3.85419	4.63454
.149	34.2692	2368.37	4762.62	9.13003	5.23637	6.30887
.199	34.6164	2074.75	4746.84	11.0461	6.21156	7.50256
.249	35.0125	1829.06	4731.53	12.4207	6.83223	8.27634
.299	35.4386	1644.49	4717.32	13.3565	7.17843	8.72369
.348999	35.881	1516.55	4704.26	13.9639	7.3302	8.93861
.398998	36.3299	1433.4	4692.18	14.3401	7.35381	8.9993
.448998	36.7793	1382.4	4680.85	14.561	7.29821	8.96385
.498997	37.2254	1352.97	4670.08	14.6816	7.19696	8.87226
.548997	37.6661	1337.31	4659.75	14.7395	7.07175	8.7506
.598996	38.1004	1330.07	4649.74	14.7596	6.93604	8.6151
.648995	38.5277	1327.77	4640.02	14.7578	6.79778	8.47546
.698995	38.9481	1328.2	4630.53	14.7438	6.66147	8.33724
.748994	39.3617	1330.05	4621.25	14.7237	6.5295	8.20343
.798993	39.7687	1332.53	4612.17	14.701	6.40297	8.07546
.848993	40.1694	1335.18	4603.27	14.6777	6.28228	7.9539
.898992	40.5643	1337.75	4594.55	14.6549	6.16742	7.83883
.948991	40.9535	1340.13	4585.99	14.6331	6.05816	7.73004
.998991	41.3375	1342.26	4577.58	14.6126	5.95422	7.62721
1.04899	41.7164	1344.11	4569.33	14.5935	5.85523	7.52998
1.099	42.0907	1345.7	4561.22	14.5758	5.76086	7.43797
1.149	42.4604	1347.03	4553.26	14.5593	5.67077	7.35081
1.199	42.8259	1348.11	4545.43	14.5442	5.58465	7.26818
1.249	43.1874	1348.97	4537.73	14.5302	5.50222	7.18974

1.3490	43.899	1350.09	4522.7	14.5052	5.34743	7.04437
1.3990	44.2496	1350.39	4515.36	14.4941	5.27461	6.97694
1.44901	44.5968	1350.52	4508.14	14.4839	5.20459	6.91272
1.49901	44.941	1350.5	4501.03	14.4745	5.13719	6.85152

PRESSURE AFTER EXTENDED TIME = 4626.65
ELEVATION CYLINDER STROKE = 8.07513
TEMPERATURE COMPENSATION VOLUME = 179.419

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
1.54902	44.9437	2515.87	4615.2	7.40125	-1.9699	-2.62737
1.59902	44.7578	1694.57	4623.74	12.7888	-3.42661	-4.56001
1.64902	44.5069	1249.5	4631.89	14.911	-4.03169	-5.34913
1.69902	44.231	1087.34	4639.18	15.6065	-4.26245	-5.63689
1.74903	43.946	1035.96	4646.15	15.8138	-4.36476	-5.753
1.79903	43.6567	1021.11	4653.06	15.8663	-4.42678	-5.81531
1.84903	43.3647	1017.77	4660.02	15.8704	-4.47698	-5.86176
1.89903	43.0706	1018.06	4667.07	15.8593	-4.52434	-5.90424
1.94904	42.7744	1019.54	4674.22	15.8432	-4.57171	-5.9465
1.99904	42.476	1021.46	4681.48	15.8251	-4.62	-5.98976
2.04903	42.1754	1023.57	4688.84	15.8061	-4.66958	-6.03445
2.09903	41.8726	1025.81	4696.32	15.7865	-4.72059	-6.08077
2.14903	41.5673	1028.16	4703.91	15.7663	-4.77314	-6.12884
2.19902	41.2597	1030.62	4711.63	15.7455	-4.82733	-6.17876
2.24902	40.9495	1033.19	4719.47	15.7242	-4.88324	-6.23062
2.29902	40.6366	1035.88	4727.44	15.7022	-4.94098	-6.28454
2.34901	40.3211	1038.69	4735.55	15.6797	-5.00063	-6.34061
2.39901	40.0026	1041.63	4743.81	15.6564	-5.06232	-6.39897
2.449	39.6812	1044.7	4752.21	15.6324	-5.12616	-6.45975
2.499	39.3566	1047.92	4760.76	15.6076	-5.19228	-6.52309
2.549	39.0292	1065.04	4826.55	15.5235	-5.24096	-6.56428
2.59899	38.7	1079.99	4832.93	15.4481	-5.29454	-6.61148
2.64899	38.3679	1086.97	4839.5	15.4067	-5.36226	-6.67611
2.69899	38.0323	1091.19	4846.22	15.3769	-5.43709	-6.74925
2.74898	37.6929	1094.55	4853.09	15.3507	-5.5166	-6.82783
2.79898	37.3495	1097.7	4860.12	15.3251	-5.60008	-6.91088
2.84898	37.0018	1100.92	4867.31	15.2991	-5.6874	-6.99824
2.89897	36.6497	1104.3	4874.66	15.2722	-5.7787	-7.09003
2.94897	36.2929	1107.92	4882.19	15.2441	-5.87423	-7.18652
2.99897	35.9311	1111.8	4889.9	15.2146	-5.9743	-7.28805
3.04896	35.5641	1115.97	4897.81	15.1836	-6.07925	-7.39499
3.09896	35.1916	1120.47	4905.94	15.151	-6.18949	-7.50781
3.14895	34.8133	1125.34	4914.29	15.1164	-6.30548	-7.62699
3.19895	34.4289	1130.62	4922.87	15.0798	-6.4277	-7.75308
3.24895	34.038	1136.35	4931.72	15.0409	-6.55675	-7.88673



File _NSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]SIMULATION.P07;1 (1620,5,0), last revised on 5-MAR-1987 13:24, is a 37 block sequential file owned by UIC [M90,GREEN_JE]. The records are variable length with implied (CR) carriage control. The longest record is 93 bytes.

Job SIMULATION (95) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:54 from queue LNSYS.

Digital Equipment Corporation - VAX/VMS Version V4.4

DYNAMIC ANALYSIS
ENERGY I VERY ELEVATION : 05-Mar-87 01:12 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	-25.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	33.750
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.099	33.94	2796.95	4239.88	5.17463	3.02491	3.63598
.199	34.4362	2405.37	4202.32	8.84889	5.02698	6.06385
.299	35.1116	2085.31	4158.35	10.963	5.99767	7.27077
.398998	35.8635	1905.78	4115.19	11.9734	6.29108	7.67044
.498997	36.6322	1829.09	4074.65	12.3645	6.24353	7.65925
.598996	37.3899	1806.86	4036.78	12.4573	6.05753	7.47796
.698995	38.1263	1808.61	4001.28	12.423	5.83084	7.24401
.798993	38.8385	1828.99	3892.73	12.2893	5.5803	6.9771
.898992	39.5199	1873.5	3845.45	12.0229	5.29434	6.6615
.998991	40.173	1905.05	3801.15	11.8245	5.06027	6.40696
1.099	40.8028	1929.86	3759.47	11.6621	4.85874	6.1902
1.199	41.4122	1950.66	3720.08	11.5214	4.68026	5.99992
1.299	42.0036	1968.73	3682.76	11.3956	4.51962	5.82998
1.39901	42.5789	1984.73	3647.28	11.2812	4.37359	5.67664
1.49901	43.1395	1999.05	3613.48	11.1763	4.23994	5.53736
1.59902	43.6869	2011.95	3581.21	11.0795	4.11698	5.41021
1.69902	44.2179	2055.76	3459.06	10.7942	3.93271	5.20001
1.79903	44.729	2089.4	3413.61	10.566	3.77866	5.02675
1.89903	45.2245	2114.11	3370.56	10.3908	3.6508	4.88599
1.99904	45.7069	2134.49	3329.63	10.2412	3.53783	4.76325
2.09903	46.1777	2152.38	3290.61	10.1062	3.43498	4.65246
2.19902	46.6378	2168.56	3253.33	9.98132	3.33999	4.55081
2.29902	47.0882	2183.4	3217.64	9.86438	3.2516	4.45678
2.39901	47.5295	2197.1	3183.42	9.75424	3.16899	4.36942
2.499	47.9577	2244.68	3041.79	9.40745	3.01424	4.18051

					8.11693	2.88307	4.02152
2.69894	48.7631	2311.99	2939.5	8.88543	2.77521	3.89287
2.798	49.1468	2336.43	2892.58	8.68418	2.68022	3.78049
2.8989	49.5197	2358.1	2848.06	8.50033	2.59364	3.67843
2.99897	49.8828	2377.83	2805.7	8.32845	2.51339	3.58394
3.09896	50.2368	2396.03	2765.34	8.16595	2.43837	3.49563
3.19895	50.5822	2412.91	2726.8	8.01145	2.36791	3.41265
3.29894	50.9195	2428.64	2689.94	7.86409	2.30153	3.33443
3.39894	51.2493	2443.34	2654.66	7.72329	2.23885	3.26055
3.49893	51.5719	2457.09	2620.83	7.58856	2.17957	3.19064
3.59892	51.8876	2469.97	2588.36	7.45952	2.12342	3.12439
3.69891	52.1969	2482.05	2557.15	7.33581	2.07016	3.06154
3.79891	52.5001	2493.4	2527.12	7.21712	2.01959	3.00185
3.8989	52.7974	2504.07	2498.19	7.10316	1.97151	2.94509
3.99889	53.0892	2514.11	2470.3	6.99368	1.92576	2.89108
4.09889	53.3758	2523.56	2443.38	6.88844	1.88216	2.83964
4.19888	53.6573	2532.47	2417.38	6.78722	1.8406	2.79061
4.29887	53.934	2540.87	2392.23	6.68984	1.80093	2.74384
4.39886	54.2062	2548.8	2367.9	6.59609	1.76304	2.6992
4.49886	54.474	2556.28	2344.34	6.50581	1.72683	2.65657
4.59885	54.7376	2563.35	2321.5	6.41884	1.69218	2.61583
4.69884	54.9972	2570.02	2299.35	6.33504	1.65902	2.57689
4.79883	55.2531	2576.34	2277.85	6.25426	1.62726	2.53964
4.89883	55.5053	2582.31	2256.96	6.17637	1.59682	2.50401
4.99882	55.754	2587.95	2236.66	6.10127	1.56763	2.4699
5.09881	55.9993	2593.3	2216.91	6.02882	1.53962	2.43725
5.19881	56.2415	2598.35	2197.7	5.95894	1.51274	2.40598
5.2988	56.4806	2603.14	2178.98	5.89151	1.48692	2.37604
5.39879	56.7168	2607.66	2160.74	5.82646	1.46211	2.34736
5.49878	56.9501	2611.95	2142.97	5.76369	1.43827	2.31989
5.59878	57.1808	2616	2125.62	5.70312	1.41534	2.29358
5.69877	57.4089	2619.84	2108.69	5.64468	1.39329	2.26837
5.79876	57.6495	2503.24	2792.27	6.86811	1.68571	2.75808
5.89876	57.9553	2349.22	2788.72	8.20988	2.00073	3.29442
5.99875	58.2984	2268.65	2785.2	8.82405	2.13346	3.53851
6.09874	58.6585	2229.09	2781.74	9.10355	2.18305	3.64878
6.19873	59.0263	2208.29	2778.34	9.24081	2.19768	3.70274
6.29873	59.3982	2195.44	2774.98	9.31965	2.19817	3.7341
6.39872	59.7728	2185.82	2771.64	9.37494	2.19307	3.75688
6.49871	60.1495	2177.48	2768.34	9.42092	2.18588	3.77683
6.5987	60.5282	2169.62	2765.06	9.46336	2.17798	3.79631
6.6987	60.9088	2161.9	2761.81	9.50464	2.16993	3.81628
6.79869	61.2914	2154.19	2758.58	9.54571	2.16195	3.83718
6.89868	61.6762	2146.44	2755.38	9.58698	2.15413	3.85921
6.99868	62.0633	2138.61	2752.2	9.62861	2.14651	3.88248
7.09867	62.4527	2130.69	2749.05	9.6707	2.1391	3.90708
7.19866	62.8447	2122.67	2745.91	9.71327	2.13189	3.93308
7.29865	63.2394	2114.56	2742.8	9.75638	2.1249	3.96055
7.39865	63.6368	2106.34	2739.72	9.80003	2.11813	3.98957
7.49864	64.0373	2098.01	2736.65	9.84425	2.11156	4.02022
7.59863	64.4409	2089.57	2733.6	9.88907	2.10521	4.0526
7.69862	64.8478	2081.01	2730.58	9.93452	2.09907	4.0868
7.79862	65.2583	2072.32	2727.57	9.9806	2.09314	4.12293
7.89861	65.6725	2063.5	2724.58	10.0273	2.08742	4.1611
7.9986	66.0906	2054.55	2721.62	10.0748	2.08192	4.20144
8.09864	66.5128	2045.45	2718.67	10.123	2.07663	4.24411
8.19868	66.9394	2036.21	2715.74	10.1719	2.07156	4.28925
8.29872	67.3707	2026.81	2712.82	10.2216	2.0667	4.33704
8.39876	67.8069	2017.26	2709.93	10.272	2.06205	4.38766
8.4988	68.189	2497.57	2708.87	6.44858	1.28654	2.77158
8.59884	68.4328	2601.9	2707.61	5.2549	1.04432	2.26785
8.69888	68.6554	2613.67	2706.23	5.09277	1.00854	2.20641
8.79893	68.876	2614.03	2704.83	5.07695	1.00195	2.20826
8.89897	69.0975	2612.55	2703.44	5.08509	1.00011	2.22083
8.99901	69.3203	2610.75	2702.05	5.09741	.999115	2.23561

9.09905	69.5446	2608.89	2700.67	5.1106	.998434	2.25449
9.1990	69.7705	2606.99	2699.29	5.12411	.997534	2.26734
9.299	69.998	2605.08	2697.91	5.13784	.996825	2.28404
9.39917	70.2273	2603.14	2696.54	5.15178	.99616	2.30132
9.49921	70.4583	2601.19	2695.17	5.16595	.995542	2.3192
9.59925	70.6911	2599.21	2693.8	5.18033	.99497	2.3377
9.69929	70.9259	2597.22	2692.44	5.19496	.994447	2.35687
9.79933	71.1625	2595.2	2691.07	5.20982	.993974	2.37673
9.89937	71.4012	2593.16	2689.72	5.22495	.993554	2.39731
9.99941	71.642	2591.09	2688.36	5.24034	.993186	2.41867
10.0995	71.8849	2589	2687.01	5.25601	.992874	2.44083

PRESSURE AFTER EXTENDED TIME = 3383.26
ELEVATION CYLINDER STROKE = 24.1001
TEMPERATURE COMPENSATION VOLUME = 426.434

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
10.1995	71.938	2465.48	3345.94	6.62742	-.93828	-2.31141
10.2995	71.5563	1290.71	3360.58	14.1265	-2.01037	-4.87964
10.3996	71.0255	790.425	3379.7	16.2973	-2.3365	-5.55821
10.4996	70.4635	673.809	3399.91	16.7546	-2.42143	-5.64199
10.5997	69.901	652.08	3420.59	16.8295	-2.45244	-5.59998
10.6997	69.344	649.531	3441.65	16.8287	-2.47297	-5.53803
10.7997	68.7933	650.798	3463.05	16.8127	-2.49173	-5.47642
10.8998	68.2485	653.052	3484.83	16.7928	-2.51032	-5.41849
10.9998	67.7094	655.802	3506.97	16.7708	-2.52901	-5.36449
11.0999	67.1773	685.027	3591.26	16.6437	-2.53203	-5.28149
11.1999	66.6517	690.826	3606.64	16.6094	-2.54937	-5.23227
11.2999	66.1305	691.842	3622.28	16.5941	-2.57004	-5.19266
11.4	65.613	692.465	3638.17	16.5803	-2.59142	-5.15684
11.5	65.099	693.302	3654.32	16.5656	-2.61314	-5.12387
11.6001	64.5881	694.427	3670.75	16.5498	-2.63516	-5.09349
11.7001	64.0802	695.851	3687.46	16.5326	-2.6575	-5.06552
11.8001	63.5749	697.574	3704.45	16.5142	-2.68014	-5.03984
11.9002	63.0721	699.589	3721.73	16.4945	-2.70312	-5.01634
12.0002	62.5715	701.898	3739.31	16.4736	-2.72644	-4.9949
12.1003	62.073	704.499	3757.21	16.4515	-2.75011	-4.97544
12.2003	61.5764	707.395	3775.42	16.428	-2.77414	-4.95785
12.3003	61.0814	710.584	3793.95	16.4033	-2.79854	-4.94208
12.4004	60.5879	714.067	3812.82	16.3774	-2.82333	-4.92805
12.5004	60.0957	717.848	3832.04	16.3501	-2.84852	-4.91569
12.6005	59.6047	721.925	3851.6	16.3215	-2.87413	-4.90495
12.7005	59.1147	726.303	3871.54	16.2916	-2.90016	-4.89579
12.8005	58.6255	730.984	3891.86	16.2603	-2.92664	-4.88815
12.9006	58.137	735.972	3912.56	16.2277	-2.95357	-4.88199
13.0006	57.6495	761.18	3996.62	16.112	-2.9659	-4.85266
13.1007	57.1654	776.589	4011.33	16.036	-2.98583	-4.83704
13.2007	56.6817	780.138	4026.33	16.0088	-3.01552	-4.83792
13.3007	56.1978	782.89	4041.62	15.9848	-3.04669	-4.84158
13.4008	55.7133	785.781	4057.21	15.9601	-3.07864	-4.84683
13.5008	55.2283	788.897	4073.1	15.9344	-3.11135	-4.85359
13.6009	54.7426	792.248	4089.31	15.9075	-3.14484	-4.86185
13.7009	54.2559	795.837	4105.85	15.8796	-3.17916	-4.87161
13.8009	53.7682	799.675	4122.73	15.8505	-3.21433	-4.8829
13.901	53.2793	803.762	4139.97	15.8202	-3.2504	-4.89573
14.001	52.789	808.106	4157.56	15.7887	-3.28742	-4.91012
14.1011	52.2973	812.714	4175.54	15.7559	-3.32542	-4.9261
14.2011	51.8038	817.595	4193.9	15.7218	-3.36446	-4.9437
14.3011	51.3085	822.756	4212.68	15.6864	-3.4046	-4.96297
14.4012	50.8112	828.204	4231.88	15.6495	-3.44589	-4.98393
14.5012	50.3117	833.951	4251.53	15.6112	-3.48839	-5.00664
14.6013	49.8098	840.008	4271.64	15.5714	-3.53217	-5.03115

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14.8014	48.7982	853.092	4313.3	15.487	-3.62385	-5.08584
14.901	48.2882	860.145	4334.91	15.4423	-3.67192	-5.11615
15.001	47.7765	894.253	4417.6	15.2803	-3.69349	-5.10981
15.1015	47.2644	905.689	4433.18	15.2158	-3.73987	-5.13812
15.2015	46.7486	910.697	4449.18	15.1789	-3.79528	-5.17866
15.3016	46.2286	915.357	4465.6	15.1434	-3.85359	-5.22284
15.4016	45.704	920.25	4482.46	15.1066	-3.91435	-5.26999
15.5016	45.1745	925.446	4499.79	15.0682	-3.97768	-5.3202
15.6017	44.6399	930.969	4517.61	15.028	-4.04378	-5.37369
15.7017	44.0997	936.84	4535.94	14.9861	-4.11285	-5.43067
15.8018	43.5537	943.079	4554.82	14.9422	-4.18514	-5.49141
15.9018	43.0014	949.717	4574.27	14.8962	-4.26091	-5.55617
16.0018	42.4424	956.775	4594.34	14.848	-4.34047	-5.6253
16.1018	41.8762	964.289	4615.06	14.7974	-4.42416	-5.69915
16.2017	41.3024	972.294	4636.47	14.7441	-4.51235	-5.77813
16.3017	40.7205	980.833	4658.63	14.688	-4.60548	-5.86271
16.4016	40.1298	989.951	4681.57	14.6287	-4.70404	-5.95343
16.5016	39.5297	999.703	4705.37	14.5661	-4.8086	-6.05089
16.6015	38.9195	1010.15	4730.09	14.4997	-4.9198	-6.15582
16.7015	38.2984	1021.36	4755.79	14.4292	-5.03839	-6.26902
16.8014	37.6677	1058.91	4843.11	14.2358	-5.12218	-6.33827
16.9013	37.0283	1076.71	4862.16	14.1325	-5.24679	-6.4575
17.0013	36.3754	1087.38	4882.13	14.0617	-5.39565	-6.60539
17.1012	35.7068	1097.69	4903.06	13.9918	-5.55959	-6.77031
17.2012	35.021	1108.9	4925.07	13.9167	-5.7387	-6.95212
17.3011	34.316	1121.4	4948.25	13.8345	-5.935	-7.15298

File _HSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]SIMULATION.P08;1 (1481,9,0), last revised on 5-MAR-1987 13:32, is a 32 block sequential file owned by UIC [M90,GREEN_JE]. The records are variable length with implied (CR) carriage control. The longest record is 93 bytes.

Job SIMULATION (96) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:53 from queue LNSYS.

ENERGY RECOVERY ELEVATION : 05-Mar-87 01:24 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	70.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	33.750
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.099	33.9781	2708.8	4622.76	6.19999	3.61625	4.34794
.199	34.5653	2174	4595.33	10.4351	5.88492	7.10539
.299	35.3479	1770.09	4568.25	12.7204	6.87012	8.34326
.398998	36.2038	1560.93	4545.14	13.7414	7.09283	8.67119
.498997	37.0689	1475.12	4525	14.1235	6.97721	8.59011
.598996	37.9173	1446.78	4506.66	14.2308	6.74591	8.36555
.698995	38.7413	1440.78	4489.5	14.2344	6.49238	8.1103
.798993	39.54	1442.02	4473.22	14.2051	6.24968	7.86504
.898992	40.3153	1444.76	4457.69	14.1695	6.02682	7.64135
.998991	41.0693	1447.11	4442.83	14.1364	5.82438	7.44045
1.099	41.8042	1448.58	4428.56	14.108	5.64042	7.26041
1.199	42.5221	1449.13	4414.85	14.0846	5.47259	7.09868
1.299	43.2247	1448.86	4401.65	14.0656	5.31873	6.95289
1.39901	43.9116	1483.28	4255.55	13.8823	5.11541	6.7397
1.49901	44.574	1523.96	4242.2	13.6671	4.91515	6.52651
1.59902	45.2196	1535.11	4229.12	13.5939	4.77705	6.3929
1.69902	45.8536	1537.08	4216.43	13.5658	4.66255	6.28915
1.79903	46.478	1536.01	4204.11	13.5529	4.55965	6.1997
1.89903	47.0939	1533.81	4192.17	13.5459	4.46429	6.11942
1.99904	47.7022	1531.06	4180.58	13.5419	4.37491	6.04636
2.09903	48.3035	1527.95	4169.32	13.54	4.29069	5.97958
2.19902	48.8984	1524.57	4158.37	13.5397	4.2111	5.91851
2.29902	49.4874	1520.94	4147.72	13.541	4.13572	5.86268
2.39901	50.0711	1517.08	4137.35	13.5436	4.06419	5.81175
2.499	50.65	1513.02	4127.24	13.5475	3.9962	5.76539

[illegible]	[illegible]	1508.76	4117.38	13.5525	3.93146	5.72332
2.69897	51.7948	1504.31	4107.76	13.5587	3.86974	5.68533
2.7981	52.3616	1499.68	4098.37	13.566	3.81082	5.6512
2.89897	52.9252	1494.89	4089.2	13.5744	3.7545	5.62075
2.99897	53.4859	1489.93	4080.23	13.5837	3.7006	5.59384
3.09896	54.0441	1484.81	4071.46	13.594	3.64896	5.57034
3.19895	54.6001	1479.54	4062.88	13.6052	3.59943	5.55014
3.29894	55.1543	1474.12	4054.48	13.6173	3.55189	5.53315
3.39894	55.7069	1468.54	4046.25	13.6303	3.50621	5.51929
3.49893	56.2583	1462.82	4038.19	13.6442	3.46229	5.50852
3.59892	56.8087	1456.95	4030.28	13.6589	3.42002	5.50079
3.69891	57.3586	1450.94	4022.53	13.6744	3.37931	5.49608
3.79891	57.9071	1481.38	3815.45	13.5123	3.29661	5.42274
3.8989	58.4418	1540.05	3808.07	13.2076	3.18286	5.29518
3.99889	58.9693	1552.21	3800.72	13.1332	3.12738	5.26256
4.09889	59.4952	1551.14	3793.48	13.1256	3.08922	5.25912
4.19888	60.0214	1546.11	3786.34	13.1381	3.05681	5.26617
4.29887	60.5486	1539.8	3779.31	13.1571	3.02677	5.27829
4.39886	61.0772	1533.01	3772.4	13.1786	2.9981	5.29396
4.49886	61.6075	1525.96	3765.59	13.2015	2.97048	5.31278
4.59885	62.1398	1518.73	3758.88	13.2254	2.94378	5.33471
4.69884	62.6745	1511.33	3752.27	13.2501	2.91795	5.35981
4.79883	63.2118	1503.77	3745.76	13.2757	2.89295	5.38821
4.89883	63.7522	1496.04	3739.35	13.3022	2.86875	5.42006
4.99882	64.2959	1488.14	3733.02	13.3296	2.84531	5.45553
5.09881	64.8434	1480.07	3726.78	13.3578	2.82261	5.49482
5.19881	65.395	1471.82	3720.63	13.387	2.80063	5.53816
5.2988	65.9511	1463.39	3714.56	13.417	2.77935	5.58582
5.39879	66.5123	1454.78	3708.57	13.4479	2.75874	5.63809
5.49878	67.0789	1445.98	3702.65	13.4798	2.73879	5.69529
5.59878	67.6515	1437	3696.81	13.5125	2.71946	5.75782
5.69877	68.1778	2260.13	3694.02	8.54952	1.706	3.67388
5.79876	68.4875	2481.97	3691.63	6.59537	1.30958	2.84904
5.89876	68.7684	2496.72	3688.94	6.43395	1.27189	2.79307
5.99875	69.048	2496.38	3686.25	6.42627	1.26486	2.80399
6.09874	69.3294	2494.51	3683.57	6.43453	1.26102	2.82253
6.19873	69.6126	2492.44	3680.91	6.44471	1.2576	2.84267
6.29873	69.8979	2490.33	3678.26	6.45534	1.2543	2.86381
6.39872	70.1854	2488.2	3675.63	6.46625	1.2511	2.88592
6.49871	70.4751	2486.04	3673.01	6.47743	1.24798	2.90905
6.5987	70.7672	2483.85	3670.4	6.48891	1.24495	2.93325
6.6987	71.0618	2481.63	3667.8	6.50068	1.24201	2.95859
6.79869	71.359	2479.38	3665.22	6.51276	1.23916	2.98513
6.89868	71.6588	2477.1	3662.65	6.52518	1.23641	3.01294
6.99868	71.9615	2474.79	3660.09	6.53793	1.23376	3.04211

PRESSURE AFTER EXTENDED TIME = 4017.21
ELEVATION CYLINDER STROKE = 24.1001
TEMPERATURE COMPENSATION VOLUME = 298.095

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
7.09867	71.859	2223.15	4037.05	8.71934	-1.23576	-3.03485
7.19866	71.4573	1396.39	4043.47	13.6189	-1.94078	-4.69287
7.29865	70.9606	1081.56	4050.51	15.0643	-2.16171	-5.12996
7.39865	70.4433	998.275	4057.65	15.416	-2.22862	-5.18894
7.49864	69.9255	976.417	4064.89	15.4989	-2.25771	-5.15982
7.59863	69.4118	968.578	4072.24	15.5215	-2.27853	-5.11455
7.69862	68.9026	963.877	4079.7	15.5306	-2.2978	-5.06883
7.79862	68.3979	960.004	4087.28	15.5362	-2.31694	-5.02569
7.89861	67.8973	956.499	4094.98	15.5401	-2.33625	-4.98556
7.9986	67.4006	953.262	4102.8	15.5428	-2.35578	-4.94834
8.09864	66.9075	950.276	4110.75	15.5444	-2.37555	-4.91386

8.19868	66.4177	947.526	4118.82	15.5449	-2.39559	-4.88196
8.2987	65.931	945.008	4127.03	15.5444	-2.41589	-4.85249
8.39876	65.4471	942.713	4135.37	15.5429	-2.43648	-4.82531
8.4988	64.9659	940.635	4143.85	15.5405	-2.45736	-4.80031
8.59884	64.487	938.769	4152.47	15.537	-2.47855	-4.77737
8.69888	64.0103	937.112	4161.24	15.5327	-2.50006	-4.7564
8.79893	63.5356	935.657	4170.16	15.5274	-2.52189	-4.73732
8.89897	63.0628	934.401	4179.23	15.5212	-2.54408	-4.72004
8.99901	62.5915	933.34	4188.47	15.5141	-2.56662	-4.7045
9.09905	62.1218	932.473	4197.86	15.5061	-2.58953	-4.69063
9.19909	61.6534	931.795	4207.42	15.4973	-2.61284	-4.67837
9.29913	61.186	931.305	4217.16	15.4876	-2.63655	-4.66768
9.39917	60.7198	931.001	4227.07	15.4771	-2.66067	-4.65852
9.49921	60.2543	930.881	4237.16	15.4656	-2.68524	-4.65084
9.59925	59.7896	930.945	4247.45	15.4534	-2.71026	-4.64461
9.69929	59.3253	931.192	4257.92	15.4402	-2.73576	-4.63979
9.79933	58.8615	931.623	4268.6	15.4263	-2.76174	-4.63637
9.89937	58.3978	932.236	4279.49	15.4114	-2.78826	-4.63433
9.99941	57.9347	933.033	4290.58	15.3957	-2.81528	-4.63364
10.0995	57.4716	934.013	4301.89	15.3791	-2.84285	-4.6343
10.1995	57.008	935.181	4313.43	15.3616	-2.87103	-4.63629
10.2995	56.5442	936.536	4325.21	15.3433	-2.8998	-4.6396
10.3996	56.08	938.082	4337.23	15.324	-2.92921	-4.64424
10.4996	55.6164	957.27	4388.31	15.2279	-2.94453	-4.62713
10.5997	55.1536	961.337	4398.71	15.1974	-2.97308	-4.63142
10.6997	54.69	962.673	4409.28	15.1787	-3.00482	-4.6409
10.7997	54.2253	963.884	4420.03	15.1604	-3.03761	-4.65215
10.8998	53.7595	965.217	4430.97	15.1415	-3.07127	-4.66486
10.9998	53.2923	966.694	4442.09	15.1219	-3.10584	-4.67904
11.0999	52.8237	968.32	4453.42	15.1015	-3.14135	-4.69472
11.1999	52.3534	970.097	4464.95	15.0803	-3.17787	-4.71191
11.2999	51.8813	972.029	4476.69	15.0583	-3.21543	-4.73068
11.4	51.4072	974.12	4488.65	15.0354	-3.2541	-4.75105
11.5	50.931	976.371	4500.84	15.0118	-3.29393	-4.77308
11.6001	50.4525	978.788	4513.26	14.9872	-3.33501	-4.79684
11.7001	49.9716	981.375	4525.92	14.9618	-3.37738	-4.82237
11.8001	49.488	984.138	4538.84	14.9354	-3.42114	-4.84975
11.9002	49.0016	987.081	4552.02	14.908	-3.46636	-4.87907
12.0002	48.5122	990.21	4565.48	14.8797	-3.51313	-4.91039
12.1003	48.0195	993.535	4579.23	14.8503	-3.56156	-4.94383
12.2003	47.5234	997.062	4593.27	14.8198	-3.61174	-4.97947
12.3003	47.0236	1000.8	4607.62	14.7881	-3.6638	-5.01745
12.4004	46.5198	1004.76	4622.3	14.7553	-3.71786	-5.05789
12.5004	46.0119	1008.94	4637.32	14.7212	-3.77407	-5.10093
12.6005	45.4996	1013.37	4652.7	14.6858	-3.83257	-5.14673
12.7005	44.9823	1008.3	4631.92	14.6931	-3.90529	-5.21114
12.8005	44.4576	1004.15	4649.09	14.696	-3.98066	-5.27833
12.9006	43.927	1008.87	4666.8	14.6586	-4.04877	-5.33532
13.0006	43.3905	1014.91	4685.09	14.6149	-4.11876	-5.39432
13.1007	42.8481	1021.47	4704.02	14.5685	-4.19189	-5.4569
13.2007	42.2991	1028.5	4723.62	14.5196	-4.26853	-5.52351
13.3007	41.7433	1036	4743.93	14.4682	-4.34899	-5.59449
13.4008	41.1804	1060.22	4846.1	14.3392	-4.41059	-5.64077
13.5008	40.6154	1091.67	4859.61	14.1753	-4.4645	-5.67729
13.6009	40.0436	1099.99	4873.66	14.1182	-4.55685	-5.76232
13.7009	39.4626	1105.49	4888.19	14.0739	-4.65999	-5.86019
13.8009	38.8714	1110.97	4903.22	14.0294	-4.77066	-5.96658
13.901	38.2691	1116.86	4918.8	13.9823	-4.88906	-6.08163
14.001	37.6548	1123.29	4934.95	13.9322	-5.01603	-6.20625
14.1011	37.0276	1130.34	4951.75	13.8784	-5.15265	-6.3416
14.2011	36.3863	1138.11	4969.23	13.8207	-5.30018	-6.48909
14.3011	35.7295	1146.71	4987.49	13.7582	-5.46017	-6.65041
14.4012	35.0558	1156.28	5006.58	13.6902	-5.63445	-6.8276
14.5012	34.3636	1166.99	5026.61	13.6157	-5.82526	-7.02311

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   SS             II     MMMM   MMMM  UU        UU  LL            AA      AA      TT          II     00      00  NN      NN
   SS             II     MM  MM   MM  UU        UU  LL            AA      AA      TT          II     00      00  NNNN    NN
   SS             II     MM  MM   MM  UU        UU  LL            AA      AA      TT          II     00      00  NNNN    NN
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           SS     II     MM       MM  UU        UU  LL            AAAAAAAAAA      TT          II     00      00  NN    NNNN
           SS     II     MM       MM  UU        UU  LL            AA      AA      TT          II     00      00  NN      NN
           SS     II     MM       MM  UU        UU  LL            AA      AA      TT          II     00      00  NN      NN
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DYNAMIC ANALYSIS
ENERGY RECOVERY ELEVATION : 05-Mar-87 01:33 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	160.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	33.750
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.099	33.9936	2668.72	4777.27	6.61391	3.85419	4.63454
.199	34.6164	2074.75	4746.84	11.0461	6.21156	7.50256
.299	35.4386	1644.49	4717.32	13.3565	7.17843	8.72369
.398998	36.3299	1433.4	4692.18	14.3401	7.35381	8.9993
.498997	37.2254	1352.97	4670.08	14.6816	7.19696	8.87226
.598996	38.1004	1330.07	4649.74	14.7596	6.93604	8.6151
.698995	38.9481	1328.2	4630.53	14.7438	6.66147	8.33724
.798993	39.7687	1332.53	4612.17	14.701	6.40297	8.07546
.898992	40.5643	1337.75	4594.55	14.6549	6.16742	7.83883
.998991	41.3375	1342.26	4577.58	14.6126	5.95422	7.62721
1.099	42.0907	1345.7	4561.22	14.5758	5.76086	7.43797
1.199	42.8259	1348.11	4545.43	14.5442	5.58465	7.26818
1.299	43.545	1349.63	4530.15	14.5172	5.42322	7.11523
1.39901	44.2496	1350.39	4515.36	14.4941	5.27461	6.97694
1.49901	44.941	1350.5	4501.03	14.4745	5.13719	6.85152
1.59902	45.6204	1350.06	4487.12	14.4579	5.00959	6.73748
1.69902	46.2889	1349.14	4473.61	14.4439	4.89069	6.63359
1.79903	46.9475	1347.8	4460.48	14.4321	4.77954	6.53882
1.89903	47.597	1346.08	4447.69	14.4225	4.67533	6.45229
1.99904	48.2383	1344.03	4435.25	14.4147	4.57737	6.37328
2.09903	48.872	1341.68	4423.12	14.4087	4.48505	6.30114
2.19902	49.4988	1339.05	4411.29	14.4043	4.39786	6.23534
2.29902	50.1193	1336.17	4399.74	14.4013	4.31534	6.1754
2.39901	50.7341	1333.05	4388.46	14.3996	4.23711	6.12094
2.499	51.3423	1351.96	4316.63	14.2964	4.13322	6.02835

2.69899	52.5341	1365.86	4287.34	14.201	3.97019	5.9045
2.7989	53.1224	1365.34	4273.17	14.1884	3.90335	5.86333
2.8989	53.707	1363.94	4259.31	14.1801	3.84036	5.82762
2.99897	54.2882	1362.14	4245.75	14.1739	3.78039	5.79628
3.09896	54.8664	1360.04	4232.48	14.1693	3.72309	5.76893
3.19895	55.4421	1357.7	4219.48	14.166	3.66826	5.7454
3.29894	56.0156	1355.12	4206.74	14.1641	3.61572	5.72555
3.39894	56.5873	1352.32	4194.24	14.1633	3.56533	5.7093
3.49893	57.1576	1349.3	4181.98	14.1638	3.51696	5.69658
3.59892	57.7268	1346.06	4169.95	14.1654	3.47049	5.68735
3.69891	58.2952	1342.6	4158.14	14.1682	3.42581	5.68157
3.79891	58.8634	1338.93	4146.54	14.1721	3.38281	5.67925
3.8989	59.4314	1335.05	4135.14	14.1772	3.34143	5.68039
3.99889	59.9996	1330.96	4123.93	14.1834	3.30157	5.68502
4.09889	60.5685	1326.66	4112.91	14.1907	3.26317	5.69319
4.19888	61.1384	1322.15	4102.07	14.1991	3.22613	5.70496
4.29887	61.7096	1317.43	4091.41	14.2086	3.19041	5.72041
4.39886	62.2826	1312.49	4080.91	14.2193	3.15593	5.73966
4.49886	62.8577	1307.34	4070.57	14.231	3.12266	5.76283
4.59885	63.4353	1301.98	4060.39	14.2438	3.09052	5.79008
4.69884	64.0158	1296.39	4050.36	14.2578	3.05949	5.8216
4.79883	64.5997	1290.59	4040.48	14.2728	3.0295	5.85759
4.89883	65.1874	1284.56	4030.73	14.289	3.00053	5.8983
4.99882	65.7795	1278.32	4021.12	14.3062	2.97253	5.94402
5.09881	66.3764	1271.85	4011.64	14.3246	2.94546	5.99507
5.19881	66.9786	1265.17	4002.29	14.344	2.91929	6.05184
5.2988	67.5869	1258.27	3993.06	14.3644	2.89398	6.11476
5.39879	68.1593	2146.26	3987.22	9.3922	1.87471	4.03475
5.49878	68.4897	2445.06	3983.26	6.95661	1.38126	3.0052
5.59878	68.7857	2463.92	3919.25	6.76302	1.33658	2.93684
5.69877	69.0784	2468.58	3913.42	6.706	1.3193	2.92769
5.79876	69.3719	2467.44	3907.63	6.70613	1.31339	2.94408
5.89876	69.6673	2465.73	3901.88	6.71204	1.30869	2.96381
5.99875	69.9647	2463.92	3896.16	6.71882	1.3042	2.98481
6.09874	70.2643	2462.09	3890.48	6.72596	1.29984	3.00689
6.19873	70.5661	2460.22	3884.82	6.73343	1.2956	3.03009
6.29873	70.8703	2458.32	3879.2	6.74123	1.29146	3.05448
6.39872	71.177	2456.38	3873.61	6.74938	1.28744	3.08013
6.49871	71.4863	2454.41	3868.05	6.75789	1.28354	3.1071
6.5987	71.7985	2452.41	3862.52	6.76677	1.27976	3.13549

PRESSURE AFTER EXTENDED TIME = 4292.96
ELEVATION CYLINDER STROKE = 24.1001
TEMPERATURE COMPENSATION VOLUME = 179.419

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
6.6987	71.9772	2695.57	4278.28	3.66299	-.518317	-1.27881
6.79869	71.7047	1865.09	4283.24	11.1103	-1.57793	-3.85198
6.89868	71.2631	1326.59	4290.19	13.9504	-1.99338	-4.78457
6.99868	70.7711	1154.21	4297.45	14.7368	-2.12041	-4.99666
7.09867	70.2702	1108.31	4304.8	14.9312	-2.16398	-5.00695
7.19866	69.7711	1094.92	4312.23	14.9797	-2.1871	-4.97126
7.29865	69.2761	1089.19	4319.75	14.9941	-2.20567	-4.9279
7.39865	68.7855	1085.32	4327.35	15.0002	-2.22339	-4.88537
7.49864	68.2989	1082.02	4335.04	15.0038	-2.24108	-4.84534
7.59863	67.8172	1097.13	4398.2	14.9258	-2.24682	-4.78238
7.69862	67.3413	1101.79	4403.9	14.8939	-2.25965	-4.73759
7.79862	66.8692	1099.74	4409.68	14.8919	-2.27731	-4.7051
7.89861	66.4002	1096.67	4415.52	14.8944	-2.29603	-4.67659
7.9986	65.9338	1093.58	4421.42	14.8969	-2.31514	-4.65049
8.09864	65.47	1090.64	4427.4	14.8987	-2.33454	-4.62646

8.19868	65.0084	1087.87	4433.45	14.8997	-2.35421	-4.60434
8.2987	64.549	1085.27	4439.57	14.8999	-2.37418	-4.58406
8.39876	64.0915	1082.83	4445.76	14.8993	-2.39445	-4.56552
8.4988	63.6358	1080.55	4452.03	14.898	-2.41502	-4.54867
8.59884	63.1817	1078.42	4458.37	14.8959	-2.43594	-4.53344
8.69888	62.7291	1076.43	4464.79	14.8932	-2.45719	-4.51977
8.79893	62.2777	1074.59	4471.29	14.8897	-2.4788	-4.50761
8.89897	61.8275	1072.88	4477.88	14.8856	-2.50079	-4.49693
8.99901	61.3783	1071.31	4484.54	14.8808	-2.52316	-4.48767
9.09905	60.9299	1069.87	4491.29	14.8754	-2.54594	-4.47982
9.19909	60.4823	1068.56	4498.13	14.8694	-2.56914	-4.47333
9.29913	60.0352	1067.37	4505.06	14.8627	-2.59279	-4.46818
9.39917	59.5885	1066.3	4512.08	14.8555	-2.6169	-4.46435
9.49921	59.1423	1065.35	4519.19	14.8476	-2.64148	-4.46183
9.59925	58.6963	1064.51	4526.39	14.8392	-2.66657	-4.46059
9.69929	58.2503	1063.79	4533.7	14.8302	-2.69218	-4.46063
9.79933	57.8043	1063.19	4541.1	14.8206	-2.71834	-4.46193
9.89937	57.358	1062.69	4548.61	14.8104	-2.74507	-4.46451
9.99941	56.9114	1062.31	4556.23	14.7997	-2.77241	-4.46834
10.0995	56.4643	1062.03	4563.95	14.7884	-2.80037	-4.47345
10.1995	56.0166	1061.87	4571.79	14.7765	-2.82898	-4.47982
10.2995	55.5683	1061.81	4579.74	14.7641	-2.85828	-4.48748
10.3996	55.1191	1061.86	4587.81	14.7511	-2.88829	-4.49644
10.4996	54.669	1062.02	4596	14.7375	-2.91906	-4.5067
10.5997	54.2177	1062.28	4604.32	14.7233	-2.95061	-4.51829
10.6997	53.7653	1062.65	4612.77	14.7086	-2.98299	-4.53124
10.7997	53.3115	1063.13	4621.35	14.6932	-3.01625	-4.54557
10.8998	52.8561	1063.72	4630.07	14.6773	-3.05041	-4.56131
10.9998	52.3992	1064.43	4638.93	14.6607	-3.08553	-4.5785
11.0999	51.9404	1065.24	4647.94	14.6436	-3.12167	-4.59717
11.1999	51.4797	1066.17	4657.1	14.6258	-3.15887	-4.61738
11.2999	51.0169	1067.21	4666.41	14.6073	-3.1972	-4.63917
11.4	50.5518	1068.38	4675.89	14.5882	-3.23672	-4.66259
11.5	50.0843	1069.66	4685.54	14.5684	-3.27749	-4.68772
11.6001	49.6143	1071.06	4695.36	14.5479	-3.31959	-4.71461
11.7001	49.1414	1072.6	4705.37	14.5267	-3.36311	-4.74334
11.8001	48.6655	1074.27	4715.56	14.5047	-3.40812	-4.774
11.9002	48.1866	1076.07	4725.95	14.4819	-3.45471	-4.80668
12.0002	47.7042	1078.01	4736.55	14.4584	-3.503	-4.84147
12.1003	47.2182	1080.09	4747.35	14.4339	-3.5531	-4.8785
12.2003	46.7285	1090.51	4815.52	14.371	-3.59568	-4.90501
12.3003	46.2381	1112.66	4823.6	14.2531	-3.62586	-4.9148
12.4004	45.7446	1115.95	4831.91	14.2224	-3.68005	-4.95708
12.5004	45.2466	1117.28	4840.42	14.2007	-3.73914	-5.00558
12.6005	44.7434	1118.51	4849.13	14.1792	-3.80114	-5.05754
12.7005	44.235	1119.85	4858.03	14.157	-3.86601	-5.11285
12.8005	43.7208	1121.35	4867.16	14.1338	-3.93395	-5.17171
12.9006	43.2006	1123.01	4876.51	14.1096	-4.00522	-5.23439
13.0006	42.6739	1124.85	4886.1	14.0843	-4.08009	-5.3012
13.1007	42.1403	1126.88	4895.95	14.0579	-4.15889	-5.37248
13.2007	41.5993	1129.13	4906.06	14.0301	-4.24199	-5.44864
13.3007	41.0504	1131.62	4916.47	14.0009	-4.3298	-5.53012
13.4008	40.4931	1134.36	4927.18	13.9701	-4.42278	-5.61742
13.5008	39.9268	1137.39	4938.22	13.9376	-4.52146	-5.71114
13.6009	39.3508	1140.74	4949.61	13.9032	-4.62646	-5.81193
13.7009	38.7643	1144.44	4961.39	13.8667	-4.7385	-5.92059
13.8009	38.1665	1148.57	4973.58	13.8277	-4.85839	-6.038
13.901	37.5565	1153.16	4986.21	13.786	-4.98709	-6.16524
14.001	36.9332	1158.29	4999.33	13.7411	-5.12574	-6.30354
14.1011	36.2955	1164.04	5012.99	13.6927	-5.27568	-6.45439
14.2011	35.642	1170.53	5027.24	13.64	-5.43851	-6.61954
14.3011	34.9712	1177.89	5042.14	13.5823	-5.61616	-6.80114
14.4012	34.2814	1186.28	5057.76	13.5186	-5.81099	-7.00179

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SS              II      MM  MM  MM  UU       UU  LL          AA    AA      TT          II      OO      OO  NNNN     NN
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  SSSSSS        II      MM       MM  UU       UU  LL          AA    AA      TT          II      OO      OO  NN  NN   NN
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       SS       II      MM       MM  UU       UU  LL          AA    AA      TT          II      OO      OO  NN       NN
       SS       II      MM       MM  UU       UU  LL          AA    AA      TT          II      OO      OO  NN       NN
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File _NSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]SIMULATION.P10;2 (6177,28339,0), last revised on 5-MAR-1987 14:06, is a 16 block sequential file owned by UIC [M90,GREEN_JE]. The records are variable length with implied (CR) carriage control. The longest record is 93 bytes.

Job SIMULATION (98) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:52 from queue LNSYS.

DYNAMIC ANALYSIS
ENERGY OVERY ELEVATION : 05-Mar-87 01:49 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	10.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	0.000
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.498997	3.90254	1956.2	5217.4	11.6369	10.9579	12.4878
.998991	10.4553	1749.42	4887.36	12.9546	11.5498	12.9964
1.49901	16.7317	1837.17	4568.96	11.871	10.6528	11.9856
1.99904	22.4604	1959.63	4249.01	10.9575	9.59117	10.9067
2.499	27.6619	2069.98	3975.08	10.0641	8.59621	9.9645
2.99897	32.134	2090.02	3629.36	9.75314	6.37219	7.56811
3.49893	35.3098	2298.92	3315.68	8.05982	4.362	5.29579
3.99889	37.6237	2442.95	3024.54	6.64048	3.19252	3.94899
4.49886	39.3	2567.76	2824.74	5.12656	2.27974	2.86254
4.99882	40.6029	2559.89	2923.59	5.13432	2.15721	2.74289
5.49878	42.0084	2532.58	2832.05	5.38187	2.13379	2.75257
5.99875	43.3226	2549.09	2751.74	5.0807	1.91405	2.50489
6.49871	44.5203	2563.83	2682.27	4.79573	1.72807	2.29312
6.99868	45.6707	2507.29	2799.81	5.4485	1.88457	2.53618
7.49864	46.9939	2457.47	2785.15	5.94744	1.9666	2.69213
7.9986	48.3454	2432.42	2770.93	6.14525	1.94478	2.71188
8.4988	49.706	2408.04	2757.13	6.33046	1.92066	2.73151
8.99901	51.078	2383.07	2743.72	6.51705	1.89855	2.75746
9.49921	52.4646	2357.39	2730.68	6.706	1.87841	2.79034
9.99941	53.8695	2330.91	2717.98	6.89785	1.86009	2.83074
10.4996	55.2967	2303.53	2705.59	7.09322	1.84351	2.8795
10.9998	56.7505	2275.15	2693.5	7.29285	1.8286	2.93773
11.5	58.2362	2245.6	2681.69	7.49765	1.81536	3.00693
12.0002	59.7596	2214.71	2670.13	7.70867	1.80381	3.08912
12.5004	61.3278	2182.26	2658.81	7.92726	1.79404	3.18699

13.0006	62.9497	2147.96	2647.7	8.65565	1.78062	3.56426
13.500	64.636	2111.45	2636.8	8.39407	1.7805	3.44611
14.001	66.401	2072.27	2626.08	8.64685	1.77724	3.62
14.5012	68.2001	2396.87	2616.95	5.55285	1.10764	2.38704
15.0014	69.1981	2472.85	2611.84	4.5048	.884614	1.97111
15.5016	70.1897	2469.29	2567.13	4.50804	.872165	2.01215
16.0018	71.2152	2461.01	2559.34	4.5803	.873224	2.09215

PRESSURE AFTER EXTENDED TIME = 3670.55
ELEVATION CYLINDER STROKE = 48.1097
TEMPERATURE COMPENSATION VOLUME = 379.151

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
16.5016	71.7065	1623.16	3680.92	11.4742	-1.62956	-3.97832
17.0013	69.1934	793.119	3737.59	15.503	-2.28342	-5.08714
17.501	66.7039	785.35	3799.2	15.4868	-2.37494	-4.88204
18.0007	64.3007	784.679	3865.3	15.4391	-2.47148	-4.73938
18.5005	61.9582	814.808	3993.82	15.2969	-2.55636	-4.61175
19.0002	59.6678	820.461	4047.94	15.1792	-2.66927	-4.56182
19.4999	57.3902	824.78	4106.46	15.1056	-2.79765	-4.55301
19.9996	55.1092	833.391	4170.02	15.0112	-2.93996	-4.57602
20.4994	52.8088	846.487	4239.44	14.8945	-3.09956	-4.63109
20.9991	50.4725	864.479	4315.74	14.753	-3.28095	-4.72054
21.4988	48.0819	888.046	4400.27	14.5825	-3.49036	-4.84919
21.9985	45.6156	918.239	4494.81	14.3767	-3.73673	-5.02529
22.4983	43.0472	949.972	4586.61	14.1574	-4.04246	-5.27401
22.998	40.3243	978.864	4673.14	13.9435	-4.44632	-5.63795
23.4977	37.3874	1056.93	4881.27	13.4802	-4.91679	-6.0696
23.9974	34.1889	1107.85	4939.88	13.1306	-5.67427	-6.83254
24.4972	30.4594	1164.23	5017.6	12.7274	-6.99666	-8.22725
24.9969	25.8876	1114.26	5189.95	12.8476	-8.30091	-9.54934
25.4966	21.2224	1186.96	5378.13	12.3235	-8.13524	-9.22147
25.9963	16.63	1205.14	5478.03	12.0856	-8.13754	-9.15478
26.4961	12.0633	1227.23	5586.47	11.8266	-8.11025	-9.11538
26.9958	7.38716	1208.61	5710.04	11.7951	-8.23031	-9.30169
27.4955	4.06593	2130.23	7133.59	3.82624	-2.70075	-3.07636
27.9952	2.64143	2150.1	7163.11	3.32868	-2.36069	-2.70073
28.495	1.35083	2159.32	7197.7	3.00546	-2.14039	-2.45963
28.9947	.183825	2167.96	7230.17	2.67412	-1.91147	-2.20635

File _NSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]SIMULATION.P11;3 (1473,4,0), last revised on 5-MAR-1987 14:31, is a 14 block sequential file owned by UIC [M90,GREEN_JE]. The records are variable length with implied (CR) carriage control. The longest record is 93 bytes.

Job SIMULATION (99) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:52 from queue LNSYS.

Digital Equipment Corporation - VAX/VMS Version V4.4

DYNAMIC ANALYSIS
ENERGY OVERY ELEVATION : 05-Mar-87 02:21 PM

EQUILIBRATION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	70.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	0.000
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.498997	3.91447	1943.18	5246.29	11.7105	11.0268	12.5658
.998991	10.552	1699.16	4971.99	12.8144	11.7846	13.2594
1.49901	17.0646	1681.02	4828.97	12.7032	11.3838	12.8123
1.99904	23.3104	1756.3	4539.5	12.0982	10.5486	12.0254
2.499	29.2474	1648.13	4429.95	12.4904	10.0372	11.7254
2.99897	34.3309	1640.53	4196.81	12.372	7.07076	8.52272
3.49893	38.1166	1729.53	4096.15	11.7637	5.52392	6.86211
3.99889	41.3434	1719.39	4052.26	11.7191	4.77405	6.11582
4.49886	44.1874	1817.29	3825.92	11.0585	4.03354	5.33143
4.99882	46.7519	1831.94	3734.95	10.8875	3.62928	4.95237
5.49878	49.1596	1836.33	3655.42	10.7843	3.32705	4.69373
5.99875	51.4591	1834.62	3584.6	10.7234	3.08987	4.51503
6.49871	53.66	1872.02	3446.77	10.4211	2.82586	4.28461
6.99868	55.7738	1876.61	3368.07	10.3278	2.65227	4.1804
7.49864	57.8484	1874.82	3296.25	10.2782	2.511	4.12539
7.9986	59.906	1868.41	3230.07	10.261	2.39339	4.11243
8.4988	61.9675	1857.6	3168.59	10.2744	2.29493	4.14107
8.99901	64.0287	1883.54	3035.23	10.0507	2.15618	4.10422
9.49921	66.0983	1877.74	2961.58	10.0364	2.0737	4.18582
9.99941	68.1741	2315.27	2895.39	6.45551	1.28823	2.77387
10.4996	69.2771	2442.15	2862.34	4.93263	.967455	2.16156
10.9998	70.3728	2436.32	2830.78	4.96155	.957341	2.22329
11.5	71.5026	2429.95	2799.92	4.99787	.949043	2.29881

PRESSURE AFTER EXTENDED TIME = 4017.22
ELEVATION CYLINDER STROKE = 48.1097

96

TEMPERATURE COMPENSATION VOLUME = 298.095

DEPRESS. CYCLE TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
12.0002	71.0429	1092.95	4049.12	14.1998	-2.03529	-4.84482
12.5004	68.6034	957.29	4083.89	14.7717	-2.19579	-4.79544
13.0006	66.248	941.706	4121.35	14.792	-2.28626	-4.6355
13.5008	63.9594	931.567	4161.86	14.7868	-2.38229	-4.52611
14.001	61.7151	926.16	4205.79	14.7591	-2.48523	-4.45663
14.5012	59.4972	925.098	4253.63	14.7106	-2.59659	-4.42066
15.0014	57.29	928.231	4305.96	14.6417	-2.71817	-4.41461
15.5016	55.0827	955.108	4399.84	14.4626	-2.83442	-4.40958
16.0018	52.865	961.459	4451.9	14.3748	-2.98682	-4.4669
16.5016	50.6105	970.997	4508.55	14.2697	-3.1606	-4.55708
17.0013	48.3018	984.313	4570.66	14.1439	-3.36173	-4.68485
17.501	45.9181	1002.03	4639.35	13.9933	-3.59909	-4.85864
18.0007	43.4233	1006.28	4683.06	13.9019	-3.91298	-5.1267
18.5005	40.7899	1077.42	4854.29	13.4803	-4.21448	-5.3687
19.0002	38.0035	1109.14	4924.37	13.2394	-4.68769	-5.81754
19.4999	34.9361	1145.37	5008.18	12.9626	-5.37034	-6.50175
19.9996	31.4344	1207.82	5113.79	12.5287	-6.43148	-7.60574
20.4994	27.1957	1196.48	5256.82	12.4564	-7.9978	-9.25134
20.9991	22.5768	1211.86	5411.73	12.2305	-8.02478	-9.12846
21.4988	18.0569	1247.38	5526.41	11.8955	-7.9616	-8.97139
21.9985	13.4973	1008.93	5119.63	13.0325	-8.88723	-9.98479
22.4983	8.60394	1212.7	5737.41	11.807	-8.20255	-9.25119
22.998	4.60519	2104.05	7684.1	4.29729	-3.02772	-3.44366
23.4977	3.27079	2165.57	7177.1	3.07157	-2.17383	-2.482
23.9974	2.08136	2172.12	7205.42	2.79296	-1.98438	-2.27447
24.4972	.997741	2178.26	7232.2	2.5093	-1.78906	-2.05857
24.9969	.241735E-01	2183.94	7257.04	2.22069	-1.58815	-1.83432

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SS                 II       MMMM   MMMM  UU       UU  LL           AA    AA       TT          II        OO      OO   NN       NN
SS                 II       MM  MM  MM  UU       UU  LL           AA    AA       TT          II        OO      OO   NNNN     NN
SS                 II       MM  MM  MM  UU       UU  LL           AA    AA       TT          II        OO      OO   NNNN     NN
  SSSSSS           II       MM      MM  UU       UU  LL           AA    AA       TT          II        OO      OO   NN  NN   NN
  SSSSSS           II       MM      MM  UU       UU  LL           AA    AA       TT          II        OO      OO   NN  NN   NN
        SS         II       MM      MM  UU       UU  LL           AAAAAAAAAA     TT          II        OO      OO   NN    NNNN
        SS         II       MM      MM  UU       UU  LL           AAAAAAAAAA     TT          II        OO      OO   NN    NNNN
        SS         II       MM      MM  UU       UU  LL           AA    AA       TT          II        OO      OO   NN      NN
        SS         II       MM      MM  UU       UU  LL           AA    AA       TT          II        OO      OO   NN      NN
SSSSSSSS       IIIIIII     MM      MM  UUUUUUUUUU  LLLLLLLLLL     AA    AA       TT       IIIIIII      OOOOOO     NN      NN
SSSSSSSS       IIIIIII     MM      MM  UUUUUUUUUU  LLLLLLLLLL     AA    AA       TT       IIIIIII      OOOOOO     NN      NN


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File _HSC000$DUA5:[M90.GREEN_JE.VMS.PROGRAMS.LTHD]SIMULATION.P12;1 (1615,17,0), last revised on 5-MAR-1987 14:50, is a 14 block sequential file owned by UIC [M90,GREEN_JE]. The records are variable length with implied (CR) carriage control. The longest record is 93 bytes.

Job SIMULATION (100) queued to LNSYS on 5-MAR-1987 14:51 by user M90E05, UIC [M90,GREEN_JE], under account M93 at priority 100, started on printer _VENUS$TXM6: on 5-MAR-1987 14:52 from queue LNSYS.

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ENERGY P*COVERY ELEVATION : 05-Mar-87 02:32 PM

EQUILIB..ION CYLINDER PARAMETERS:

PISTON AREA	IN^2	5.52
EQULIBRATOR VOLUME	IN^3	1200.00
AMBIENT TEMPERATURE	deg-F	160.00
AMBIENT PRESSURE	LB/IN^2	14.70
BALANCE PRESSURE	LB/IN^2	5414.00
BALANCE POSITION	DEG	0.00
CHARGE PRESSURE AT 70 deg-F & 14.7 PSI	LB/IN^2	2690.00
X LOCATION OF WIRE ROPE	INCH	-2.00
Y LOCATION OF WIRE ROPE	INCH	35.50

ELEVATION CYLINDER PARAMETERS:

MAXIMUM MANUAL PRESSURE	LB/IN^2	3000.000
MAXIMUM MANUAL POWER INPUT	HP	0.300
STARTING DECELERATION PRESS	LB/IN^2	3000.000
MAXIMUM DECELERATION TORQUE	FT-LB	10000.000
ENERGY STORAGE ACCUMULATOR GAS VOLUME	IN^3	2500.000
ENERGY STORAGE ACCUMULATOR GAS PRESSURE	LB/IN^2	3000.000
PISTON DIAMETER	INCH	3.000
ROD DIAMETER	INCH	1.500
GAIN VALUE		0.650

SYSTEM PARAMETERS:

STARTING ELEVATION (THETAo)	DEGREES	0.000
ENDING ELEVATION (THETAf)	DEGREES	72.000
ELEVATING WEIGHT	LBS	6348.450
MASS MOMENT OF INERTIA (I)	SLUG-FT^2	40176.600

ELEVATION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ELEVATION FLOWRATE (GPM)	EQUILIBRATOR FLOWRATE (GPM)	ANGULAR VELOCITY (DEG/SEC)
.498997	3.92036	1938.02	5256.53	11.7395	11.0538	12.5964
.998991	10.6295	1650.6	5031.65	13.061	12.0078	13.5096
1.49901	17.2563	1642.07	4865.24	12.899	11.55	13.0021
1.99904	23.6594	1650.39	4652.7	12.6546	11.0161	12.5721
2.499	29.8086	1516.14	4482.48	13.156	10.121	11.8585
2.99897	34.8835	1548.54	4321.44	12.8394	7.11309	8.60832
3.49893	38.7323	1634.51	4203.1	12.2691	5.59832	6.99288
3.99889	42.0002	1661.35	4107.28	12.0233	4.76923	6.15173
4.49886	44.9369	1668.4	4026.3	11.8959	4.2226	5.63145
4.99882	47.6215	1737.01	3842.86	11.425	3.70068	5.10891
5.49878	50.1211	1720.29	3799.27	11.4476	3.43011	4.90873
5.99875	52.5276	1721.52	3721.44	11.371	3.17956	4.72816
6.49871	54.8601	1717.94	3651.12	11.3263	2.97656	4.61164
6.99868	57.1484	1709.64	3586.87	11.3128	2.80965	4.55007
7.49864	59.4181	1699.52	3500.83	11.3127	2.66708	4.53266
7.9986	61.6774	1698.78	3442.01	11.2604	2.53008	4.53286
8.4988	63.9631	1679.28	3388.51	11.3205	2.43161	4.62028
8.99901	66.3084	1654.19	3339.37	11.4143	2.34981	4.77296
9.49921	68.4593	2380.23	3301.21	5.73773	1.1398	2.47735
9.99941	69.677	2389.54	3280.22	5.57955	1.08772	2.46422
10.4996	70.9306	2381.29	3259.89	5.62829	1.07732	2.55375

PRESSURE AFTER EXTENDED TIME = 4292.97
ELEVATION CYLINDER STROKE = 48.1097
TEMPERATURE COMPENSATION VOLUME = 179.419

DEPRESSION CYCLE

TIME (SEC)	ELEVATION (DEG)	ELEVATION PRESSURE (PSI)	EQUILIBRATOR PRESSURE (PSI)	ANGULAR VELOCITY (DEG/SEC)		
10.9998	71.8778	2189.43	4280.1	7.52442	-1.06614	-2.62021
11.5	69.6631	1089.11	4313.57	14.1897	-2.07513	-4.69889
12.0002	67.3634	1096.88	4403.33	14.1039	-2.13901	-4.48776
12.5004	65.1515	1083.28	4431.24	14.1177	-2.22486	-4.36906
13.0006	62.9876	1071.75	4460.77	14.1206	-2.31791	-4.29205
13.5008	60.854	1063.57	4492.07	14.1066	-2.41821	-4.24743
14.001	58.735	1058.28	4525.36	14.0777	-2.52751	-4.23152
14.5012	56.6169	1055.6	4560.86	14.035	-2.64787	-4.24262
15.0014	54.4873	1055.38	4598.85	13.9789	-2.78184	-4.28065
15.5016	52.3316	1057.59	4639.71	13.9093	-2.93288	-4.3471
16.0018	50.135	1062.31	4683.88	13.8253	-3.10561	-4.44529
16.5016	47.8802	1069.76	4731.97	13.7251	-3.30649	-4.58094
17.0013	45.5576	1108.52	4834.3	13.4684	-3.50773	-4.71391
17.501	43.1407	1114.68	4876.66	13.3662	-3.80286	-4.9666
18.0007	40.5764	1124.6	4924.45	13.2396	-4.17671	-5.30927
18.5005	37.8093	1140.59	4979.54	13.0749	-4.67257	-5.78898
19.0002	34.7501	1167.56	5045.24	12.8427	-5.37596	-6.49964
19.4999	31.2376	1219.15	5128.17	12.4624	-6.48414	-7.65901
19.9996	26.9551	1180.86	5240.06	12.5319	-8.05564	-9.30841
20.4994	22.307	1191.64	5371.69	12.3314	-8.10091	-9.20812
20.9991	17.7223	1205.95	5459.62	12.1142	-8.11947	-9.14527
21.4988	13.1543	1219.32	5553.15	11.9033	-8.12818	-9.13233
21.9985	8.51026	1092.85	5400.01	12.4597	-8.65894	-9.76733
22.4983	4.30345	2083.2	7169.54	4.58646	-3.23476	-3.68218
22.998	2.55355	2097.54	7066.5	4.24245	-3.0096	-3.4441
23.4977	.852761	2098.98	7093.38	4.08958	-2.91709	-3.35838

PART NUMBER: 12585718, 12585719, Energy Storage Accumulator

DESCRIPTION: This is a dual-function accumulator. One function is to store energy to power the hydraulic system, the other function is to return the cannon to battery during counter-recoil.

Nitrogen Volume: 4800 cu. in. (2400 cu. in. each)
Pre-Charge Pressure: 2640 psi at 70 F

STATUS:

Mounting, size, flow, pressure and cycle life requirements have been determined and were provided to York to be finalized.

AUTHOR: Jeff Ireland

ACCUMULATOR SIZING (ENERGY STORAGE)

$V_O = 4800.\ IN^3$ $\quad T_H = 160°F = 620°R$ $\quad \Delta V_{BS} = 650.\ IN^3$

$P_{RELIEF} = 3800.\ PSI$ $\quad T_C = 70°F = 530°R$ $\quad P_{SYS} = 3000.\ PSI$

$\Delta V = 900.\ IN^3$ $\quad T_L = -25°F = 435°R$

I) $\dfrac{P_C V_O}{T_C} = \dfrac{P_R (V_O - \Delta V)}{T_H}$

$P_C = (T_C/T_H)(1 - \Delta V/V_O) P_R = \underline{2640.\ PSI}$

II $\dfrac{P_C V_O}{T_C} = \dfrac{P_L V_O}{T_L}$

$\underline{P_L} = (T_L/T_C) P_C = \underline{2166.\ PSI}$

III Δ VOLUME TO BLOW RELIEF AT 435°R

$\dfrac{P_L V_O}{T_L} = \dfrac{P_R (V_O - \Delta V_R)}{T_L}$

$\underline{\Delta V_R} = V_O (P_R - P_L)/P_R = V_O (1 - P_L/P_R) = \underline{2064.\ IN^3}$

IV PEAK PRESSURE

$\underline{P_{MAX}} = P_R \Big/ \left[1 - \frac{\Delta V_{BS}}{(V_O - \Delta V_R)}\right]^{1.4} = \underline{5555\ PSI}$

V $\underline{V_{MAX}}$ = MAX OIL IN ACCUMULATOR = $2064.\ IN^3 + 650.\ IN^3 = \underline{2714.\ IN^3}$

VI $\dfrac{P_L V_O}{T_L} = \dfrac{P_{SYS} (V_O - \Delta V_{SYS})}{T_L}$

$\underline{\Delta V_{SYS}} = V_O (1 - P_L/P_{SYS}) = \underline{1334.\ IN^3}$

VOLUME OF OIL $\geq$ 3000 PSI = $2064\ IN^3 - 1334\ IN^3 = \underline{730.\ IN^3}$

$T_H = 620°R$
$T_C = 530°R$
$T_L = 435°R$

I. $$\frac{P_C V_C}{T_C} = \frac{P_R (V_C - \Delta V)}{T_H}$$

$$P_C = (T_C/T_H)(1 - \Delta V/V_C) P_R$$

II. $$\frac{P_C V_C}{T_C} = \frac{P_L V_C}{T_L}$$ EMPTY ACCUMULATOR PRESSURE AT 435°R

$$P_L = (T_L/T_C) P_C = (T_L/T_C)(T_C/T_H)(1 - \Delta V/V_C) P_R = (T_L/T_H)(1 - \Delta V/V_C) P_R$$

III $$\frac{P_L V_C}{T_L} = \frac{P_R V_{435}}{T_L}$$ VOLUME TO BLOW RELIEF AT 435°R

$$V_{435} = (P_L/P_R) V_C = (T_L/T_H)(1 - \Delta V/V_C) V_C = (T_L/T_H)(V_C - \Delta V)$$

IV $$P_{MAX} = P_R \Big/ \left[1 - \Delta V_{BS}/V_{435}\right]^{1.4}$$

$V_C = 4800\ IN^3$
$\Delta V_{BS} = 650\ IN^3$
$P_{SYS} = 3000\ PSI$

V $$\frac{P_{SYS} V_C}{T_{SYS}} = \frac{P_C V_C}{T_C}$$

$$T_{SYS} = (P_{SYS}/P_C) T_C = (P_{SYS}/P_R)\left(\frac{1}{1 - \Delta V/V_C}\right) T_H = (P_{SYS}/P_R)\left(\frac{V_C}{V_C - \Delta V}\right) T_H = K V_C$$

VI $$\frac{P_{SYS} V_L}{T_L} = \frac{P_C V_C}{T_C}$$

$$K = (P_{SYS}/P_R)\left[T_H/(V_C - \Delta V)\right]$$

$$V_L = (P_C/P_{SYS})(T_L/T_C) V_C = (T_L/T_H)(P_R/P_{SYS})(V_C - \Delta V) = T_L/K$$

V_0	ΔV	$V_{OIL\ MAX}$	P_{MAX}	T_{SYS}	ΔV_L	ΔV_H	P_{RELIEF}
4800.	900.	2714	7309	-2°F	240.	0	5000
4800	800	2644	7230	-13.6°F	123.	100	5000
4600	900	2654	7185	22°F	446	0	4800
4600	800	2583	7098	9°F	334	100	4800
4600	700	2514	7016	-3°F	222	200	4800
4400	900	2594	6888	48°F	635	0	4600
4400	900	2594	6767	71°F	800	0	4400
4400	900	2594	6613	84°F	880	0	4300
4800	900	2714	5847	112°F	1,152 (917)	0	4000
4800	900	2714	5555	142°F	1,334 (730)	0	3800
4800	900	2714	5117	194°F	1,608 (156)	0	3500
5000	900	2774	4580	249°F	1931 (193)	0	3200
5000	900	2774	5152	170°F	1548 575	0	3600
5000	900	2774	5295	153°F	1452 (671)	0	3700

EMPLACE VOLUME

MAX. TRAVERSE FROM C/L = $(55.002\text{in} - 48.000\text{in})(\pi/4)[4.25\text{in}]^2$
= $99.332\ \text{in}^3$

MAX. ELEVATION = $227.001\ \text{in}^3$

WHEEL ACTUATOR (REAR) = $2(15.720\ \text{in}^3) = 31.440\ \text{in}^3$

WHEEL ACTUATOR (FRONT) = $2(7.024\ \text{in}^3) = 14.048\ \text{in}^3$

CANNON TO BATTERY = $(105\text{in})(\pi/4)[(3.0\text{in})^2 - (2.25\text{in})^2] = 324.713\ \text{in}^3$

RAMMER = $34.785\ \text{in}^3$

BREECH (OPEN) = $9.572\ \text{in}^3$

BREECH (CLOSE) = $11.928\ \text{in}^3$

PRIMER = $.397\ \text{in}^3$

LANYARD = $.068\ \text{in}^3$

TOTAL EMPLACE VOLUME = $753.284\ \text{in}^3$

DISPLACE VOLUME

MAX. TRAVERSE TO c/L = $(48.00 - 40.323)_{IN}(\pi/4)(4.25_{IN})^2 = \underline{108.908\ IN^3}$

MAX. DEPRESSION TO TOW = $\underline{311.905\ IN^3}$

WHEEL ACTUATOR TO TOW (REAR) = $2(38.692_{IN} - 28.128_{IN})(\pi/4)(3.25_{IN})^2 = \underline{175.272\ IN^3}$

WHEEL ACTUATOR TO TOW (FRONT) = $2(37.152_{IN} - 25.140_{IN})(\pi/4)(2.375_{IN})^2 = \underline{106.430\ IN^3}$

GUN FROM BATTERY TO STOW ≈ 1/2 CANNON TO BATTERY = $\frac{324.713\ IN^3}{2} = \underline{162.357\ IN^3}$

TOTAL DISPLACE = $\underline{864.872\ IN^3}$

[illegible]

PART NUMBER: 12525-13, Equilibration Intensifier

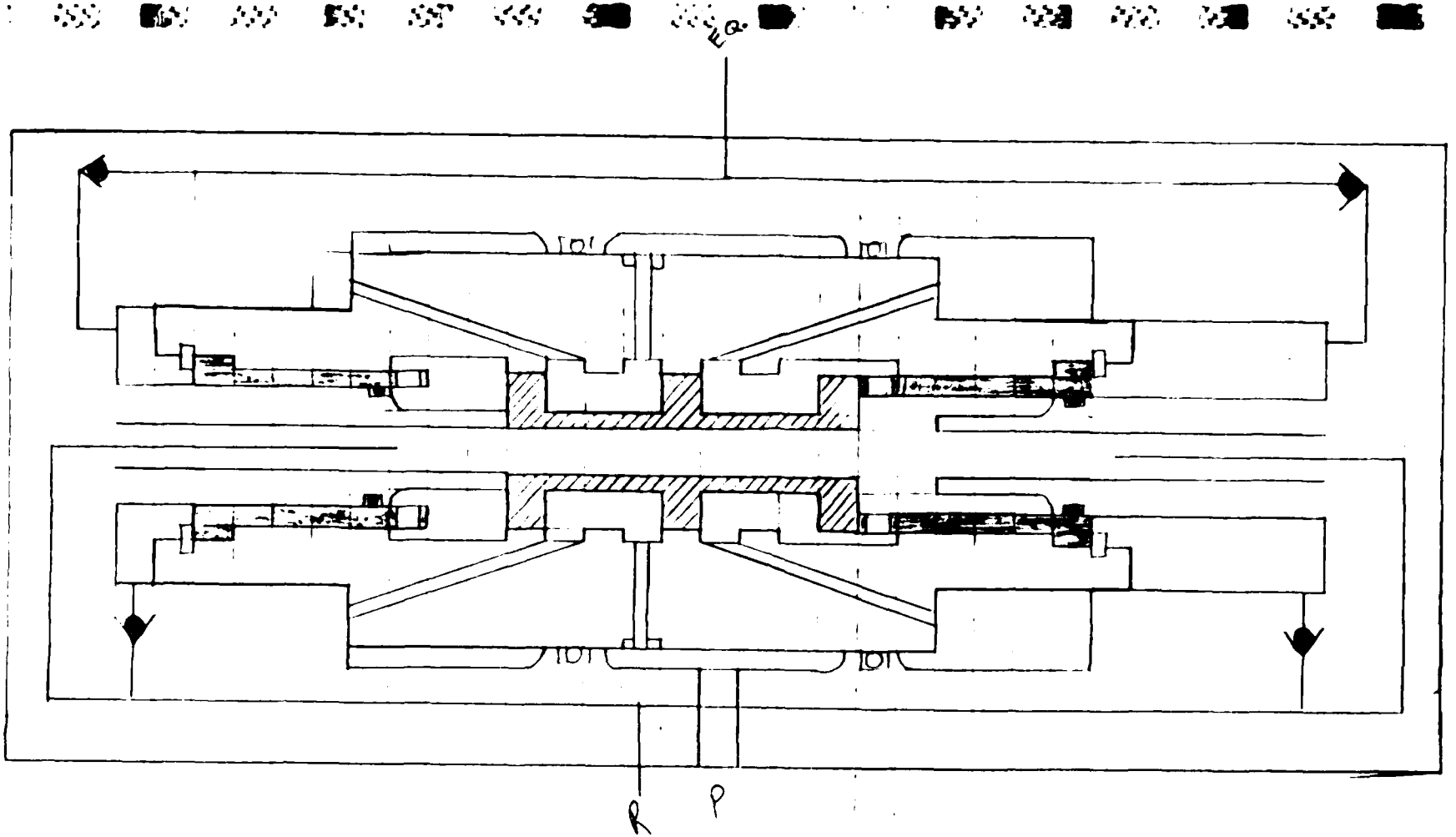
DESCRIPTION:

This device allows the carrousel to use the lower pressure oil stored in the energy recover accumulator to pump up the high pressure (54 MPa psi) equilibration accumulator.

[illegible]:

[illegible] provided to Martin [illegible]

[illegible]: [illegible]



INTENSIFIER

DESCRIPTION: FIRING STABILITY

(Note: The reader is also referred to Section C/060, Mass-Coordinate Data File, since the data was used for firing stability analysis.)

A three-dimensional stability program, called **HOP.BAS**, was originally written prior to Phase I work, but was enhanced frequently throughout the LTHD program to meet current needs.

The purpose of the program is to provide insight into firing stability by simulating LTHD firing throughout the recoil stroke and up to the time of maximum hop (at the tips of the trails). The basic inputs include component weight and CG data, system geometry, firing conditions and a recoil force profile.

The simulation is flexible to include a wide range of firing conditions. These include any combination of: firing on a forward slope, firing on a side slope, any elevation angle, any traverse angle, and any spade position or orientation with the ground.

A list of program inputs is described below:

VARIABLE NAME	DESCRIPTION
BL	Horiz. dist. from pivot point to tip of barrel, inches
SL	Horiz. dist. from pivot point to trail pad, inches, with trail in tow position
SLA	Angle between fwd. direction and trails, radians
H	Vertical trunnion height from pivot, inches
HXF	Horiz. dist. from trunnion to pivot point (point of ground contact on spade), inches
HXS	Horiz. dist. from trunnion center to side pivot plane, inches (used only in analysis of side hop)
HXCG	Horiz. dist. from CG of non-recoiling components to side pivot plane, inches (side hop analysis only)
KSP	Individual trail spring constant, lb/inch (as in a cantilevered beam)
SWED	Traverse angle of tube, degrees
EAD	QE or elevation angle of tube, degrees
SLPD	Forward slope of ground, degrees (uphill = +)
SSLPD	Side slope of ground, degrees

Data files:

LFBF.DAT	See description found in Section C/060.
LFTS.DAT	Same.
LFTE.DAT	Same.
FORCE	A data file consisting of recoil force values (lbs.) and recoil stroke values (feet) at 1.0 msec time intervals starting at t = 0 and ending at the end of the recoil stroke.

The following pages of this section contain the current program inputs, listing and corresponding outputs.

It should be noted that in early work, HOP.BAS also served the purpose of determining the maximum allowable recoil force profile for given geometry. If the LTHD were completely rigid (or at least very stiff) this information would have been useful to specify a recoil force profile that would minimize hop. However, because sufficient flexibility exists in the trails, it was determined that a recoil force profile whose peak occurs early on in the stroke and whose magnitude exceeds the "maximum allowable recoil force" curve will results in a lower hop height than if the recoil force profile were to remain under such a curve at all times. Consequently, the purpose of the program shifted more towards an analytical tool than a design tool.

A rough analysis was also performed on a 7500 lb LTHD to explore the weight-range tradeoff. This analysis was not performed under contract, but is included for the reader's reference. The calculations and results are contained at the end of this section.

STATUS:

The most recent computer runs of HOP.BAS produced the results shown in Table C/140-1. These results indicate that the LTHD remains quite stable during worst-case normal firing conditions (firing from battery position) and also remains fairly stable during a cooloff condition. The results presented are for worst-cases only. Further simple runs would indicate less and less hop as the firing QE increases.

Phase I work included varying traverse angle and forward and side slopes. It was concluded from this work that firing at non-zero traverse angles does not cause higher hop heights compared to a 0 degree traverse angle at the same QE.

Furthermore, computer runs with non-zero forward (uphill) and side slopes did show a reduction in LTHD stability (i.e, increase in hop height values). It was shown that sufficient stability was maintained when firing within the +/- 10 % hill grade requirement. The reader is referred to the Phase I Dynamic Analysis Report for additional information in this area.

AUTHOR: Scott Dacko

TABLE C/140-1 LTHD STABILITY RESULTS

SPADE ALL THE WAY IN GROUND, FIRE FROM BATTERY POSITION:

Starting Weight at Trails, pounds:	3427
Starting System CG- Z-Dir., inches:	163.44
Starting Trail Deflection, inches:	1.14
Barrel Deflection at Shot Ejection, in.:	.0036
Maximum Trail Hop Height, inches:	1.21

SPADE COMPLETELY OUT OF GROUND, FIRE FROM BATTERY POSITION:

Starting Weight at Trails, pounds:	3099
Starting System CG- Z-Dir., inches:	147.78
Starting Trail Deflection, inches:	1.03
Barrel Deflection at Shot Ejection, in.:	.026
Maximum Trail Hop Height, inches:	2.65

SPADE ALL THE WAY IN GROUND, FIRE FROM LOAD POS. (COOKOFF):

Starting Weight at Trails, pounds:	3223
Starting System CG- Z-Dir., inches:	153.68
Starting Trail Deflection, inches:	1.07
Barrel Deflection at Shot Ejection, in.:	.0064
Maximum Trail Hop Height, inches:	2.13

SPADE COMPLETELY OUT OF GROUND, FIRE FROM LOAD POS. (COOKOFF):

Starting Weight at Trails, pounds:	2895
Starting System CG- Z-Dir., inches:	138.03
Starting Trail Deflection, inches:	.965
Barrel Deflection at Shot Ejection, in.:	.048
Maximum Trail Hop Height, inches:	4.15

STABILITY COMPUTER PROGRAM

PART 1. INPUTS

PART 2. PROGRAM LISTING

PART 3. OUTPUTS

STABILITY COMPUTER PROGRAM

PART 1. INPUTS

```
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File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOP3.DAT;2 (2248,10,2), last revised on
8-APR-1987 13:07, is a 8 block sequential file owned by UIC [M20,DACKO_SG].
The records are variable length with implied (CR) carriage control.  The
longest record is 7 bytes.

Job HOP3 (1347) queued to LN on 8-APR-1987 13:11 by user M20E96, UIC
[M20,DACKO_SG], under account M22 at priority 100, started on printer
_VENUS$TXM6: on 8-APR-1987 13:14 from queue LNSYS.

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File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOP3.BAT;2 (2240,19,2), last revised on 8-APR-1987 13:09, is a 5 block sequential file owned by UIC [M20,DACKO_SG]. The records are variable length with implied (CR) carriage control. The longest record is 7 bytes.

Job HOP3 (1347) queued to LN on 8-APR-1987 13:11 by user M20E96, UIC [M20,DACKO_SG], under account M22 at priority 100, started on printer _VENUS$TXM6: on 8-APR-1987 13:13 from queue LNSYS.

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STABILITY COMPUTER PROGRAM

PART 2. PROGRAM LISTING

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22

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File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOP.BAS;12 (2457,13,2), last revised on
10-MAR-1987 17:09, is a 63 block sequential file owned by UIC [M20,DACKO_SG].
The records are variable length with implied (CR) carriage control.  The
longest record is 151 bytes.

Job HOP (1340) queued to LN on 8-APR-1987 12:56 by user M20E96, UIC
[M20,DACKO_SG], under account M22 at priority 100, started on printer
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```
 5  REM  MODIFIED TO PROVIDE BEST EST'S FOR NON-ZERO TRAVERSE
 6  REM  (FOR CGX, CGY, ETC)
 7  REM  S. DACKO
10  REM  PROGRAM HOP.BAS - WRITTEN BY S. DACKO, 07/16/85
15  REM  PROGRAM READS FROM ANY GRAVITY.BAS DATA FILES, 3/3/87
18  REM
20  REM  FOR COMPLETE WRITEUP/INSTRUCTIONS, SEE USER'S MANUAL
30  REM  THIS PROGRAM ALLOWS THE USER TO EVALUATE ARTILLERY SYSTEM
40  REM  GEOMETRY, INCLUDING RECOIL SYSTEM CHARACTERISTICS, IN TERMS
50  REM  OF "HOP" AND STABILITY.  THIS PROGRAM WILL FIND:
60  REM  1. STABILIZING MOMENTS AND MAXIMUM ALLOWABLE FORCES RESULTING
70  REM     FROM THE SYSTEM GEOMETRY
80  REM  2. STABILIZING, OVERTURNING AND SAFETY MOMENTS RESULTING FROM
90  REM     AN INPUT FORCE ACTING ON THE SYSTEM GEOMETRY
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140 DIM RWT(500),RXC(500),RYC(500)
150 DIM RXCN(500)
160 DIM RXCS(500)
170 DIM RXCNA(500),RYCNA(500)
175 DIM NXCS(500),NXCNA(500),NYCNA(500)
180 DIM F(600),X(600),X1(600)
190 DIM BRXCG(500),TSXCG(500),TEXCG(500)
930 REM
940 REM ------------------------------------------------------
950 REM FIND MAXIMUMS OR USE DATA
960 REM
970 PRINT "FIND:  1. MAX. FORCES & MOMENTS"
980 PRINT "       2. MOMENTS FROM FORCE DATA"
990 PRINT "(ENTER 1 OR 2):"
1000 INPUT FI
1010 IF FI = 1 THEN GOTO 1042
1020 PRINT "FROM:  1. RECOIL.BAS  OR  2. RECOIL.FORT"
1030 PRINT "(ENTER 1 OR 2):"
1040 INPUT PROG
1041 REM
1042 PRINT "OUTPUT TO FILE?  1-YES  2-NO  "
1043 INPUT OUT
1044 IF OUT=2 THEN GOTO 1070
1045 PRINT "ENTER FILENAME, E.G. [.OUTPUT]XXX.LIS "
1046 INPUT FILE$
1047 OPEN FILE$ FOR OUTPUT AS FILE #9, RECORDTYPE ANY
1050 REM
1060 REM ------------------------------------------------------
1070 REM DEFINE REMAINDER OF SYSTEM GEOMETRY
1080 REM
1090 REM BL = DIST (IN) FROM PIVOT POINT TO TIP OF BARREL
1100 BL = 260
1110 REM SL = DIST. (IN) FROM PIVOT TO FRONT PAD CENTER ALONG TRAIL
1120 SL = 259
1130 REM SLA = ANGLE BETW FWD DIR AND TRAILS, RADIANS
1140 SLA = 35*3.14159/180
1150 REM H = HT AT WHICH FORCE IS APPLIED, INCHES
1151 PRINT "INPUT TRUNNION HEIGHT, IN. (18.5 TO 31.25)"
1152 INPUT H
1170 REM HXF = HORIZ. DIST. FROM TRUNNION TO PT OF GND CONTACT ON SPADE
1171 PRINT "INPUT HORIZ. DIST. FROM TRUNNION TO"
1172 PRINT " POINT OF GROUND CONTACT ON SPADE, IN. (24 TO 14.25)"
1173 INPUT HXF
1190 REM HXS = HORIZ. DIST. FROM SIDE PIVOT PLANE TO WHERE INPUT FORCE IS APP
1200 HXS = 44
```

```
1210 REM HXCG = HORIZ. DIST. FROM SIDE PIVOT PLANE TO CG OF NON-REC COMPONENT
1220 HXCG = 43
1270 REM KSP = SPRING CONSTANT OF EACH TRAIL, LBS/IN
1280 PRINT "INPUT SPRING CONSTANT OF EACH TRAIL (LBS/IN)"
1285 INPUT KSP
1290 REM
1300 REM ------------------------------------------------------
1310 REM DEFINE SYSTEM CONDITION OF FIRING
1320 REM
1330 REM SWPD = ANGLE OF SWEEP, DEGREES
1335 PRINT "INPUT TRAVERSE ANGLE OF GUN, DEGREES:"
1340 INPUT SWPD
1350 SWP = 3.14159/180*SWPD
1360 REM EAD = ELEVATION ANGLE, DEGREES
1365 PRINT "INPUT ELEVATION ANGLE OF GUN, DEGREES:"
1370 INPUT EAD
1380 EA = 3.14159/180*EAD
1390 REM
1400 REM ------------------------------------------------------------
1410 REM DEFINE EXTERNAL CONDITIONS OF FIRING
1420 REM
1430 REM SLPD = SLOPE OF HILL - FORWARD, DEGREES
1435 PRINT "INPUT FORWARD (UPWARD) SLOPE OF HILL, DEGREES:"
1440 INPUT SLPD
1450 SLP = 3.14159/180*SLPD
1460 REM SSLPD = SLOPE OF HILL - SIDE, DEGREES
1465 PRINT "INPUT SIDE SLOPE OF HILL, DEGREES:"
1470 INPUT SSLPD
1480 SSLP = 3.14159/180*SSLPD
1490 REM ------------------------------------------------------
1500 REM FIND SINES AND COSINES AND OTHER CONSTANTS
1510 REM
1520 CSSLP = COS(SSLP)
1530 SSSLP = SIN(SSLP)
1540 CSLP = COS(SLP)
1550 CSLPL = CSLP
1560 SSLP = SIN(SLP)
1570 SSLPL = SSLP
1580 CEA = COS(EA)
1590 SEA = SIN(EA)
1600 CSWP = COS(SWP)
1610 SSWP = SIN(SWP)
1620 DENF = CEA*H*CSWP-SEA*HXF
1630 DENS = CEA*H*SSWP-SEA*HXS
1640 REM
1650 REM ------------------------------------------------------------
1660 REM W1 = ANGULAR VELOCITY VALUE, INITIALLY = 0
1670 W1 = 0
1680 REM HA = INITIAL HOP ANGLE, RADIANS
1690 HA = 0
1700 HAL = HA
1701 REM
1702 REM ------------------------------------------------------
1712 REM READ IN RECOIL COMPONENT DATA
1713 OPEN "[.WEIGHT]LFBR.DAT" FOR INPUT AS FILE #1, RECORDTYPE ANY
1714 REM INPUT INITIAL DATA FROM FILE TO BE IGNORED
1715 INPUT #1, DES$
1716 INPUT #1, BRWT
1717 INPUT #1, BRCGX
1718 INPUT #1, BRCGY
1719 INPUT #1, BRCGZ
1720 INPUT #1, BRJYZ
```

```
1721 INPUT #1, BRJXY
1722 INPUT #1, BRJXZ
1723 REM INPUT DATA TO BE USED, EXCEPT FOR DESN,BRXCG(I)
1724 I=1
1725 INPUT #1, BRNO
1726 INPUT #1, DESN
1727 IF (DESN = 0) THEN GOTO 1736
1728 INPUT #1, RWT(I)
1729 INPUT #1, BRXCG(I)
1730 INPUT #1, RYC(I)
1731 INPUT #1, RXC(I)
1732 RYC(I)=RYC(I)+H
1733 RXC(I)=RXC(I)+HXF
1734 I=I+1
1735 GOTO 1725
1736 CLOSE #1
1737 NRPTS=BRNO-1
1738 REM DIVIDE BARREL INTO 11 DISTRIBUTED MASS SEGMENTS
1739 FOR I = 1 TO 10
1740 RWT(NRPTS+I) = RWT(NRPTS)/11
1741 RXC(NRPTS+I) = RXC(NRPTS) - 100 + I*20
1742 RYC(NRPTS+I) = RYC(NRPTS)
1743 NEXT I
1744 RWT(NRPTS) = RWT(NRPTS+1)
1745 RXC(NRPTS) = RXC(NRPTS) - 100
1746 REM ------------------------------------------------
1748 REM FIND TOTAL SYS. WT, SYS. C.G., CGX, CGY, MASS M.I., J
1750 REM UNITS:  CG, INCHES; MASS M.I., FT-LB-S^2
1751 WT1 = 0
1752 REM READ IN NON-RECOILING / NON-ELEV/TRAV COMPONENTS
1753 REM THEN FIND C.G. OF COMPONENTS
1754 OPEN "[.WEIGHT]LFTS.DAT" FOR INPUT AS FILE #1, RECORDTYPE ANY
1755 REM INPUT INITIAL DATA FROM FILE TO BE IGNORED
1756 INPUT #1, DES$
1757 INPUT #1, TSWT
1758 INPUT #1, TSCGX
1759 INPUT #1, TSCGY
1760 INPUT #1, TSCGZ
1762 INPUT #1, TSJYZ
1763 INPUT #1, TSJXY
1764 INPUT #1, TSJXZ
1766 REM INPUT DATA TO BE USED, EXCEPT FOR TSNO,DESN,TSXCG(I)
1767 I=1
1768 INPUT #1, TSNO
1769 INPUT #1, DESN
1770 IF (DESN = 0) THEN GOTO 1785
1772 INPUT #1, NWT(I)
1773 INPUT #1, TSXCG(I)
1774 INPUT #1, NYC(I)
1775 INPUT #1, NXC(I)
1776 NYC(I)=NYC(I)+H
1777 NXC(I)=NXC(I)+HXF
1778 WT1 = WT1+NWT(I)
1779 CGST1 = CGST1 + NWT(I)/32.2*HXCG
1780 CGXT1 = CGXT1+NWT(I)/32.2*NXC(I)
1781 CGYT1 = CGYT1+NWT(I)/32.2*NYC(I)
1782 J1 = J1+((NXC(I)/12)^2+(NYC(I)/12)^2)*NWT(I)/32.2
1783 I=I+1
1784 GOTO 1768
1785 CLOSE #1
1787 REM
1788 REM READ IN NON-RECOILING / ELEV/TRAV COMPONENTS DATA
```

```
1789 REM THEN FIND C.G. OF NON-RECOILING / ELEV/TRAV COMPONENTS
1790 OPEN "[.WEIGHT]LFTE.DAT" FOR INPUT AS FILE #1, RECORDTYPE ANY
1791 REM INPUT INITIAL DATA FROM FILE TO BE IGNORED
1792 INPUT #1, DES$
1793 INPUT #1, TEWT
1794 INPUT #1, TECGX
1795 INPUT #1, TECGY
1796 INPUT #1, TECGZ
1797 INPUT #1, TEJYZ
1798 INPUT #1, TEJXY
1799 INPUT #1, TEJXZ
1800 REM INPUT DATA TO BE USED, EXCEPT FOR TENO,DESN,TEXCG(I)
1802 INPUT #1, TENO
1804 INPUT #1, DESN
1806 IF (DESN = 0) THEN GOTO 2024
1808 INPUT #1, NWT(I)
1809 INPUT #1, TEXCG(I)
1810 INPUT #1, NYC(I)
1812 INPUT #1, NXC(I)
2009 NYC(I)=NYC(I)+H
2010 NXC(I)=NXC(I)+HXF
2014 WT1 = WT1+NWT(I)
2015 NXCNA(I) = (NXC(I)-HXF)*CSWP*CEA+HXF
2016 CGXT1 = CGXT1 + NWT(I)/32.2*NXCNA(I)
2017 NYCNA(I) = H+(NYC(I)-H)*CEA+NXC(I)*SEA
2018 CGYT1 = CGYT1 + NWT(I)/32.2*NYCNA(I)
2019 NXCS(I) = (NXC(I)-HXF)*SSWP*CEA+HXS
2020 CGST1 = CGST1 + NWT(I)/32.2*NXCS(I)
2021 J1 = J1+((NXCNA(I)/12)^2+(NYCNA(I)/12)^2)*NWT(I)/32.2
2022 I=I+1
2023 GOTO 1802
2024 CLOSE #1
2074 REM
2076 WT2 = 0
2080 REM FIND C.G. OF RECOILING COMPONENTS
2090 FOR I = 1 TO NRPTS+10
2100 WT2 = WT2+RWT(I)
2110 RXCNA(I) = (RXC(I)-HXF)*CSWP*CEA+HXF
2120 CGXT2 = CGXT2 + RWT(I)/32.2*RXCNA(I)
2130 RYCNA(I) = H+(RYC(I)-H)*CEA+RXC(I)*SEA
2140 CGYT2 = CGYT2 + RWT(I)/32.2*RYCNA(I)
2150 RXCS(I) = (RXC(I)-HXF)*SSWP*CEA+HXS
2160 CGST2 = CGST2 + RWT(I)/32.2*RXCS(I)
2170 J2 = J2+((RXCNA(I)/12)^2+(RYCNA(I)/12)^2)*RWT(I)/32.2
2180 NEXT I
2190 REM
2200 WT = WT1+WT2
2210 CGX = (CGXT1+CGXT2)/(WT/32.2)
2220 CGY = (CGYT1+CGYT2)/(WT/32.2)
2230 CGS = (CGST1+CGST2)/(WT/32.2)
2240 CGR = (CGX^2+CGY^2)^.5
2250 J = J1+J2
2260 THET1 = ATN(CGY/CGX)
2270 REM ------------------------------------------------------
2280 REM FIND EQUIVALENT SPRING CONSTANT FOR TWO TRAILS
2290 KSP = KSP*2
2300 WTB = WT*CSLP*CSSLP*CGX/(EL*COS(SLA))
2310 IF KSP = 0 THEN GOTO 2340
2320 DEFL2 = WTB/KSP
2330 GOTO 2350
2340 DEFL2 = 0
2350 DEFL0 = DEFL2
```

```
2360 REM FSP = FORCE OF THE SPRING, LBS
2370 FSP = KSP*DEFL2
2380 REM GWT = PRESSURE OR WEIGHT OF THE SYSTEM ON THE GROUND
2390 GWT = FSP
2400 FSPL = FSP
2410 HAD = HA*180/3.14159
2420 REM ------------------------------------------------------
2430 PRINT "INITIAL CONDITIONS:"
2440 PRINT "WEIGHT OF RECOILING COMPONENTS (LB) = ";WT2
2450 PRINT "WEIGHT OF NON-RECOILING COMPONENTS (LB) = ";WT1
2460 PRINT "SYSTEM WEIGHT (LB) = ";WT
2470 PRINT "INDIV. TRAIL'S SPRING CONSTANT (LB/IN) = ";KSP/2
2490 PRINT " "
2500 PRINT "AT MAXIMUM EXTENSION OF BARREL:"
2510 PRINT "CGZ (IN) = ";CGX
2520 PRINT "CGY (IN) = ";CGY
2530 PRINT "CGX (IN) = ";CGS
2540 PRINT "DEFLECTION OF TRAILS (IN) = ";DEFL0
2550 PRINT "MASS MOMENT OF INERTIA (FT-LB-S^2) = ";J
2560 PRINT "  "
2570 PRINT "SWEEP ANGLE LEFT (DEGREES)                = ";SWPD
2580 PRINT "ELEVATION ANGLE (DEGREES)                 = ";EAD
2590 PRINT "UPWARD SLOPE OF HILL - FORWARD (DEGREES) = ";SLPD
2600 PRINT "UPWARD SLOPE OF HILL - SIDE    (DEGREES) = ";SSLPD
2605 PRINT "  "
2608 REM
2609 IF OUT=2 THEN GOTO 2630
2610 PRINT #9,"INITIAL CONDITIONS:"
2611 PRINT #9,"WEIGHT OF RECOILING COMPONENTS (LB) = ";WT2
2612 PRINT #9,"WEIGHT OF NON-RECOILING COMPONENTS (LB) = ";WT1
2613 PRINT #9,"SYSTEM WEIGHT (LB) = ";WT
2614 PRINT #9,"INDIV. TRAIL'S SPRING CONSTANT (LB/IN) = ";KSP/2
2616 PRINT #9," "
2617 PRINT #9,"AT MAXIMUM EXTENSION OF BARREL:"
2618 PRINT #9,"CGZ (IN) = ";CGX
2619 PRINT #9,"CGY (IN) = ";CGY
2620 PRINT #9,"CGX (IN) = ";CGS
2621 PRINT #9,"DEFLECTION OF TRAILS (IN) = ";DEFL0
2622 PRINT #9,"MASS MOMENT OF INERTIA (FT-LB-S^2) = ";J
2623 PRINT #9," "
2624 PRINT #9,"SWEEP ANGLE LEFT (DEGREES)                = ";SWPD
2625 PRINT #9,"ELEVATION ANGLE (DEGREES)                 = ";EAD
2626 PRINT #9,"UPWARD SLOPE OF HILL - FORWARD (DEGREES) = ";SLPD
2627 PRINT #9,"UPWARD SLOPE OF HILL - SIDE    (DEGREES) = ";SSLPD
2628 PRINT #9," "
2629 REM
2630 IF FI = 2 THEN GOTO 2720
2640 PRINT "STROKE,","CG-Z,  ","MAX FORCE","STA MOM","CG X,  ","MAX FORCE"
2650 PRINT "FEET   ","INCHES ","LBS, W/O ","FT-LBS ","INCHES ","LBS, W/O"
2660 PRINT "       ","       ","BACKW HOP","       ","       ","SIDE HOP"
2670 PRINT "-------","-------","---------","-------","-------","--------"
2680 REM
2681 IF OUT=2 THEN GOTO 2960
2682 PRINT #9,"STROKE,","CG-Z,  ","MAX FORCE","STA MOM","CG X,  ","MAX FORCE"
2683 PRINT #9,"FEET   ","INCHES ","LBS, W/O ","FT-LBS ","INCHES ","LBS, W/O"
2684 PRINT #9,"       ","       ","BACKW HOP","       ","       ","SIDE HOP"
2685 PRINT #9,"-------","-------","---------","-------","-------","--------"
2690 GOTO 2960
2700 REM ------------------------------------------------------
2710 REM INPUT FORCE DATA FROM SPECIFIED DATA FILE
2720 PRINT "ENTER INPUT FORCE DATAFILE NAME, E.G., [.OUTPUT]XXX.LIS "
2740 INPUT FORC$
```

```
2750 OPEN FORC$ FOR INPUT AS FILE #1, RECORDTYPE ANY
2760 P = 0
2770 P = P+1
2780 INPUT #1, F(P)
2790 IF F(P) = -9999 THEN GOTO 2840
2800 REM
2810 INPUT #1, X1(P)
2820 IF PROG = 2 THEN X1(P) = X1(P)*12
2830 GOTO 2770
2840 CLOSE #1
2850 P = P-1
2860 ST = 1
2870 B = 1
2880 PRINT "DATA FILE:  ";FORC$
2890 PRINT "  "
2900 PRINT "  "
2910 PRINT "STROKE,","CG -Z,","STABLE ","OVERTURN-","SAFETY","WT. AT"
2920 PRINT "INCHES ","INCHES","MOMENT,","ING MOM.,","MOMENT","EA TRAIL,"
2930 PRINT "       ","      ","FT-LBS ","FT-LBS   ","FT-LBS","LBS  "
2940 PRINT "-------","------","-------","---------","------","------"
2941 IF OUT=2 THEN GOTO 3060
2942 PRINT #9,"DATA FILE:  ";FORC$
2943 PRINT #9,"  "
2944 PRINT #9,"  "
2945 PRINT #9,"STROKE,","CG -Z,","STABLE ","OVERTURN-","SAFETY","WT. AT"
2946 PRINT #9,"INCHES ","INCHES","MOMENT,","ING MOM.,","MOMENT","EA TRAIL,"
2947 PRINT #9,"       ","      ","FT-LBS ","FT-LBS   ","FT-LBS","LBS  "
2948 PRINT #9,"-------","------","-------","---------","------","------"
2950 GOTO 3060
2960 FOR P = 0 TO 102
2970 X1(P) = P
2980 NEXT P
2990 ST = 3
3000 B = 0
3010 P = 102
3020 REM
3030 REM ------------------------------------------------------
3040 REM FIND THE NET MOMENT ON THE SYSTEM FOR EACH TIME T
3050 REM
3060 FOR N = B TO P STEP ST
3070 CGXT2 = 0
3080 CGYT2 = 0
3090 CGST2 = 0
3100 J2 = 0
3110 REM ------------------------------------------------------
3120 REM CHANGE SYS. X-COORD, C.G. X'S,C.G., MASS M.I., J
3130 REM
3140 FOR I = 1 TO NRPTS+10
3150 RXCN(I) = RXC(I) - X1(N)
3160 RXCNA(I) = (RXCN(I)-HXF)*CSWP*CEA+HXF
3170 RXCS(I) = (RXCN(I)-HXF)*SSWP*CEA+HXS
3180 CGST2 = CGST2 + RWT(I)/32.2*RXCS(I)
3190 CGXT2 = CGXT2 + RWT(I)/32.2*RXCNA(I)
3200 RYCNA(I) = RYC(I)+RXCN(I)*SEA
3210 CGYT2 = CGYT2 + RWT(I)/32.2*RYCNA(I)
3220 J2 = J2 + ((RXCNA(I)/12)^2+(RYCNA(I)/12)^2)*RWT(I)/32.2
3230 NEXT I
3240 CGS = (CGST1+CGST2)/(WT/32.2)
3250 CGX = (CGXT1+CGXT2)/(WT/32.2)
3260 CGY = (CGYT1+CGYT2)/(WT/32.2)
3270 IF FI = 1 THEN GOTO 4290
3280 CGR = (CGX^2+CGY^2)^.5
```

```
3290 J = J1+J2
3300 REM ------------------------------------------------------
3310 REM CALCULATE STABILIZING, OVERTURNING AND NET MOMENTS
3320 IF N = 1 THEN GOTO 3340
3330 GOTO 3450
3340 FSP = WT*CSLP*CSSLP*CGX/(SL*COS(SLA))
3350 IF KSP = 0 THEN FSP = 0
3360 FSPL = FSP
3370 GWT = FSP
3380 IF KSP = 0 THEN GOTO 3410
3390 DEFL2 = FSP/KSP
3400 GOTO 3420
3410 DEFL2 = 0
3420 DEFL0 = DEFL2
3430 CSLP = COS(SLP)
3440 SSLP = SIN(SLP)
3450 STM = WT*CSLP*CSSLP*CGX+F(N)*SEA*HXF
3460 OTM = F(N)*CEA*CSWP*H+WT*SSLP*CSSLP*CGY+FSP*SL*COS(SLA)
3470 C = STM-OTM
3480 REM IF HT OF HOP > 0 THEN PRINT HOP HT INSTEAD OF WEIGHT ON GROUND
3490 IF HEI > 0 THEN GOTO 3570
3500 IF KSP = 0 THEN GOTO 3540
3510 REM GWT IS FORCE OF SPRING, DIVIDE BY 2 FOR 2 TRAILS
3520 GWT = GWT/2
3530 GOTO 3550
3540 GWT = (C/12)/(CSLP*CSSLP*SL)*.5
3550 PRINT X1(N),CGX,STM/12,OTM/12,C/12,GWT
3555 IF OUT=1 THEN PRINT #9,X1(N),CGX,STM/12,OTM/12,C/12,GWT
3560 GOTO 3590
3570 PRINT X1(N),CGX,STM/12,OTM/12,C/12,"HOP=";HEI
3575 IF OUT=1 THEN PRINT #9,X1(N),CGX,STM/12,OTM/12,C/12,"HOP=";HEI
3580 REM SET LAST VALUES OF OMEGA AND HOP ANGLE = CURRENT VALUES
3590 W1 = W2
3600 HAL = HA2
3610 REM FIND FIRST APPROXIMATION OF NEW HOP ANGLE
3620 REM I'S AFTER VARIABLE NAMES DENOTE INITIAL CALCULATED VALUES
3630 ALPHI = -(C/12)/J
3640 REM
3650 HAI = HAL+(.5*ALPHI*(.001)^2+W1*(.001))
3655 WI = ALPHI*(.001)+W1
3660 DXI = SIN(HAI-HAL)*SL*COS(SLA)
3670 DEFLI = DEFL2 - DXI
3680 FSPI = DEFLI*KSP
3690 IF DEFLI > 0 THEN GOTO 3710
3700 FSPI = 0
3710 CSLPI = COS(SLP+HAI)
3720 SSLPI = SIN(SLP+HAI)
3730 REM NOW USE FSPI, CS,SSLPI TO FIND NEW AVG. VALUES FOR WT & FSP
3740 CSLP = (CSLPL+CSLPI)/2
3750 SSLP = (SSLPL+SSLPI)/2
3760 STMI = WT*CSLP*CSSLP*CGX+F(N)*SEA*HXF
3770 OTMI = F(N)*CEA*CSWP*H+WT*SSLP*CSSLP*CGY+FSP*SL*COS(SLA)
3780 C = STMI-OTMI
3790 REM FIND REAL ESTIMATE OF THE NEW POSITION
3800 ALPH = -(C/12)/J
3810 REM
3820 HA2 = HAL+(.5*ALPH*(.001)^2+W1*(.001))
3825 W2 = ALPH*(.001)+W1
3830 DX = SIN(HA2-HAL)*SL*COS(SLA)
3840 DEFL2 = DEFL2 - DX
3850 IF N > 15 THEN GOTO 3880
3860 REM BDEFL = DEFLECTION (IN) OF BARREL 15 MSEC AFTER FIRING
```

```
3870 BDEFL = SIN(HA2)*BL*COS(SLA)
3880 FSP = DEFL2*KSP
3890 FSPL = FSP
3900 GWT = FSP
3970 HEI = SIN(HA2)*SL-DEFL0
4070 CSLP = COS(SLP+HA2)
4080 CSLPL = CSLP
4090 SSLP = SIN(SLP+HA2)
4100 SSLPL = SSLP
4110 REM IF BACK OF STROKE IS ENCOUNTERED AND ON GROUND, THEN STOP
4120 IF N >= P AND W2 <= 0 THEN GOTO 4210
4130 REM IF BACK OF STROKE IS ENCOUNTERED AND HOPPING, THEN KEEP
4140 REM SYSTEM AT BACK MOST POSITION
4150 IF N > P THEN GOTO 4410
4160 GOTO 4400
4210 PRINT " "
4220 PRINT "INITIAL DEFLECTION (IN) OF TRAILS = ";DEFL0
4225 IF OUT=1 THEN PRINT #9,"INIT. DEFL. (IN) OF TRAILS: ";DELF0
4230 PRINT " "
4240 GOTO 4430
4250 REM
4260 REM ------------------------------------------------------
4270 REM CALCULATIONS OF MAX FORCE VALUES, STABILIIZING MOMENTS
4280 REM
4290 NUMF = WT*(CSLP*CSSLP*CGX-SSLP*CSSLP*CGY)
4300 MAXF = NUMF/DENF
4310 IF MAXF < 0 THEN MAXF = 999999
4320 IF SWPD = 0 THEN GOTO 4360
4330 NUMS = WT*(CSSLP*CSLP*CGS-SSSLP*CSLP*CGY)
4340 MAXFS = NUMS/DENS
4350 GOTO 4380
4360 MAXFS = 999999
4370 IF MAXFS < 0 THEN MAXFS = 999999
4380 STAMF = WT*CGX*COS(SLP)/12
4390 PRINT X1(N)/12,CGX,MAXF,STAMF,CGS,MAXFS
4395 IF OUT=1 THEN PRINT #9, X1(N)/12,CGX,MAXF,STAMF,CGS,MAXFS
4400 NEXT N
4410 REM IF FI = 2 THEN GOTO 4422
4420 REM GOTO 4445
4422 N = P+1
4423 F(N) = 0
4424 X1(N) = X1(P)
4425 GOTO 3070
4426 REM
4430 PRINT " "
4440 PRINT "DEFLECTION (IN) OF GUN BARREL AFTER 15 MSEC = ";BDEFL
4442 IF OUT=1 THEN PRINT #9,"GUN BARREL DEFL. AFTER 15 MSEC: ";BDEFL
4443 REM
4445 PRINT "HOP HEIGHT VALUES, IF ANY, ARE IN INCHES"
4446 IF OUT=1 THEN PRINT #9,"HOP HT VALUES, IF ANY, ARE IN INCHES"
4460 END
```

STABILITY COMPUTER PROGRAM

PART 3. OUTPUTS

```
CCCCCCCCCC      0000000000000000000000000000000000000000000000000000      CCCCCCCCCC
CCCCCCCCCC      Digital Equipment Corporation - VAX/VMS Version V4.4       CCCCCCCCCC
CCCCCCCCCC      0000000000000000000000000000000000000000000000000000      CCCCCCCCCC

          M    M    222     000    EEEEE    999     666
          MM  MM   2   2   0   0   E       9   9   6
          M M M       2   0  00   E       9   9   6
          M    M     2    0 0 0   EEEE     9999   6666
          M    M    2     00  0   E           9   6   6
          M    M   2      0   0   E           9   6   6
          M    M  22222    000    EEEEE    999     666


     H    H    OOO    PPPP    RRRR    U    U  N    N     1
     H    H   O   O   P   P   R   R   U    U  N    N    11
     H    H   O   O   P   P   R   R   U    U  NN   N     1
     HHHHH   O   O   PPPP    RRRR    U    U  N N  N     1
     H    H   O   O   P       R R     U    U  N  NN     1
     H    H   O   O   P       R  R    U    U  N   N     1
     H    H    OOO    P       R   R    UUUUU  N   N    111

               DDDD     AAA    TTTTT     ;;     222
               D   D   A   A     T       ;;    2   2
               D   D   A   A     T             2
               D   D   A   A     T       ;;      2
               D   D   AAAAA     T       ;;     2
          ..   D   D   A   A     T        ;     2
          ..   DDDD    A   A     T       ;     22222
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File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOPRUN1.DAT;2 (216,21,2), last revised on 8-APR-1987 13:15, is a 41 block sequential file owned by UIC [M20,DACKO_SG]. The records are variable length with implied (CR) carriage control. The longest record is 87 bytes.

Job HOPRUN1 (1349) queued to LN on 8-APR-1987 13:17 by user M20E96, UIC [M20,DACKO_SG], under account M22 at priority 100, started on printer _VENUS$TXM6: on 8-APR-1987 13:17 from queue LNSYS.

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CCCCCCCCCC      0000000000000000000000000000000000000000000000000000      CCCCCCCCCC
CCCCCCCCCC      Digital Equipment Corporation - VAX/VMS Version V4.4       CCCCCCCCCC
CCCCCCCCCC      0000000000000000000000000000000000000000000000000000      CCCCCCCCCC
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```
A8600 System (VENUS)

Username: M20E96
Password:
Hello...
    Last interactive login on Wednesday,  8-APR-1987 13:00
    Last non-interactive login on Thursday, 26-MAR-1987 08:57
    Last system boot on  5-MAR-1987 22:17:49.02



THE DATE AND TIME IS
   8-APR-1987 13:04:12

VENUS> RUN HOP
FIND:  1. MAX. FORCES & MOMENTS
       2. MOMENTS FROM FORCE DATA
(ENTER 1 OR 2):
? 2
FROM:  1. RECOIL.BAS  OR  2. RECOIL.FORT
(ENTER 1 OR 2):
? 2
OUTPUT TO FILE?  1-YES  2-NO
? 2
INPUT TRUNNION HEIGHT, IN. (18.5 TO 31.25)
? 18.5
INPUT HORIZ. DIST. FROM TRUNNION TO
 POINT OF GROUND CONTACT ON SPADE, IN. (24 TO 14.25)
? 24
INPUT SPRING CONSTANT OF EACH TRAIL (LBS/IN)
? 3000
INPUT TRAVERSE ANGLE OF GUN, DEGREES:
? 0
INPUT ELEVATION ANGLE OF GUN, DEGREES:
? 0
INPUT FORWARD (UPWARD) SLOPE OF HILL, DEGREES:
? 0
INPUT SIDE SLOPE OF HILL, DEGREES:
? 0
INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) =  3870.15
WEIGHT OF NON-RECOILING COMPONENTS (LB) =  5029.85
SYSTEM WEIGHT (LB) =  8900
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) =  3000

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) =  163.435
CGY (IN) =  18.2265
CGX (IN) =  43.7133
DEFLECTION OF TRAILS (IN) =  1.14267
MASS MOMENT OF INERTIA (FT-LB-S^2) =  68595.9

SWEEP ANGLE LEFT (DEGREES)                =  0
ELEVATION ANGLE (DEGREES)                 =  0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) =  0
UPWARD SLOPE OF HILL - SIDE    (DEGREES) =  0

ENTER INPUT FORCE DATAFILE NAME, E.G., [.OUTPUT]XXX.LIS
? HOP3.DAT
DATA FILE:  HOP3.DAT
```

STROKE, INCHES	CG -Z, INCHES	STABLE MOMENT, FT-LBS	OVERTURN-ING MOM., FT-LBS	SAFETY MOMENT FT-LBS	WT. AT EA TRAI LBS
.012	163.43	121211	128919	-7708.33	3427.9
.048	163.414	121199	128919	-7720.23	3427.8
.12	163.383	121176	128920	-7744.28	3427.7
.276	163.315	121126	128942	-7816.03	3427.5
.54	163.201	121040	129024	-7983.23	3427.3
.924	163.034	120917	129251	-8334.56	3427
1.428	162.814	120754	129749	-8994.79	3426.6
2.052	162.543	120553	130658	-10105.6	3426.1
2.772	162.23	120321	132114	-11792.9	3425.5
3.552	161.891	120069	134233	-14163.6	3424.8
4.404	161.52	119794	137109	-17314.7	3424.0
5.304	161.129	119504	140816	-21311.6	3423.1
6.24	160.722	119202	145408	-26206.3	3422
7.2	160.304	118892	150870	-31977.8	3420.6
8.16	159.887	118583	157155	-38572	3419
9.132	159.464	118269	164268	-45998.2	3417.0
10.104	159.042	117956	172207	-54251.5	3414.6
11.088	158.614	117639	180970	-63331.7	3411.7
12.06	158.191	117325	190550	-73224.7	3408.2
13.044	157.763	117008	200770	-83762.1	3404.1
14.016	157.341	116694	210919	-94224.9	3399.2
15	156.913	116377	220184	-103808	3393.4
15.972	156.49	116063	227762	-111699	3386.6
16.944	156.067	115750	232871	-117122	3378.7
17.904	155.65	115440	234761	-119321	3369.7
18.864	155.232	115131	234417	-119286	3359.4
19.824	154.815	114821	234011	-119190	3347.9
20.772	154.403	114515	233562	-119047	3335.2
21.72	153.99	114210	233069	-118860	3321.3
22.656	153.583	113908	232533	-118625	3306.1
23.592	153.176	113606	231952	-118346	3289.7
24.516	152.775	113308	231327	-118019	3272.0
25.44	152.373	113010	230658	-117649	3253.0
26.352	151.976	112716	229945	-117229	3232.9
27.264	151.58	112422	229187	-116766	3211.4
28.164	151.188	112131	228385	-116254	3188.7
29.052	150.802	111845	227539	-115694	3164.8
29.94	150.416	111559	226647	-115089	3139.6
30.828	150.03	111272	225712	-114440	3113.1
31.692	149.654	110993	224732	-113738	3085.3
32.568	149.273	110711	223707	-112996	3056.3
33.42	148.903	110436	222638	-112202	3026.1
34.272	148.532	110161	221525	-111364	2994.6
35.124	148.162	109887	220368	-110481	2961.8
35.964	147.796	109616	219166	-109551	2927.8
36.792	147.436	109349	217921	-108572	2892.6
37.62	147.076	109082	216632	-107550	2856.1
38.436	146.722	108818	215299	-106481	2818.4
39.24	146.372	108559	213916	-105357	2779.5
40.044	146.022	108300	212377	-104077	2739.3
40.836	145.678	108044	210658	-102613	2698.0
41.628	145.333	107789	208773	-100984	2655.4
42.408	144.994	107537	206736	-99198.2	2611.7
43.176	144.66	107290	204559	-97269.8	2566.8
43.944	144.326	107042	202258	-95215.8	2520.7
44.7	143.998	106798	199843	-93045.3	2473.5

45.456	143.669	106554	197325	-90770.6	2425.2
46.2	143.345	106314	194718	-88404.1	2375.8
46.932	143.027	106078	192031	-85952.8	2325.3
47.664	142.709	105842	189274	-83432	2273.8
48.396	142.39	105606	186458	-80852.1	2221.2
49.104	142.083	105378	183592	-78213.9	2167.7
49.812	141.775	105149	180685	-75535.4	2113.2
50.52	141.467	104921	177746	-72825.3	2057.7
51.216	141.164	104696	174783	-70087	2001.3
51.9	140.867	104476	171803	-67327.6	1944.1
52.584	140.569	104255	168815	-64559.8	1886.0
53.256	140.277	104039	165824	-61785.5	1827.1
53.928	139.985	103822	162839	-59017.4	1767.4
54.588	139.698	103609	159854	-56245	1707.0
55.236	139.416	103400	156851	-53450.9	1645.8
55.884	139.134	103191	153831	-50640.1	1584.0
56.532	138.852	102982	150797	-47815.5	1521.5
57.168	138.576	102777	147749	-44972.6	1458.4
57.804	138.299	102572	144688	-42116.6	1394.6
58.416	138.033	102374	141615	-39240.9	1330.4
59.04	137.762	102173	138533	-36359.9	1265.6
59.652	137.496	101975	135440	-33464.1	1200.3
60.252	137.235	101782	132340	-30557.8	1134.5
60.852	136.974	101588	129233	-27644.6	1068.4
61.452	136.713	101395	126120	-24725.7	1001.9
62.04	136.457	101205	123002	-21797.1	935.06
62.616	136.207	101019	119882	-18863.2	867.89
63.192	135.956	100833	116761	-15927.5	800.46
63.756	135.711	100652	113638	-12986.1	732.80
64.32	135.466	100470	110515	-10045.6	664.95
64.884	135.221	100288	107395	-7107.45	HOP= .9
65.436	134.981	100110	104279	-4169.15	HOP= .3
65.988	134.741	99931.5	101166	-1234.34	HOP= .0
66.528	134.506	99757.3	98059.4	1697.9	HOP= .9
67.056	134.276	99587	94959.2	4627.73	HOP= .1
67.584	134.047	99416.6	91869.8	7546.79	HOP= .1
68.112	133.817	99246.3	88787.9	10458.3	HOP= .1
68.628	133.593	99079.8	85718	13361.8	HOP= .2
69.144	133.368	98913.4	82661.6	16251.8	HOP= .2
69.66	133.144	98746.9	79618.4	19128.5	HOP= .2
70.164	132.925	98584.3	76589.9	21994.4	HOP= .2
70.656	132.711	98425.5	73579	24846.6	HOP= .3
71.148	132.497	98266.8	70585.6	27681.2	HOP= .3
71.64	132.283	98108.1	67612.7	30495.4	HOP= .3
72.12	132.074	97953.2	64658.5	33294.7	HOP= .3
72.6	131.865	97798.3	61727.7	36070.7	HOP= .4
73.068	131.662	97647.4	58820	38827.4	HOP= .4
73.536	131.458	97496.4	55936.8	41559.6	HOP= .4
74.004	131.255	97345.4	53081	44264.3	HOP= .4
74.46	131.057	97198.3	50251.1	46947.1	HOP= .5
74.916	130.858	97051.1	47451.4	49599.7	HOP= .5
75.36	130.665	96907.9	44680.3	52227.6	HOP= .5
75.804	130.472	96764.6	41942.2	54822.4	HOP= .6
76.248	130.279	96621.4	39235.3	57386.1	HOP= .6
76.68	130.091	96482	36562.6	59919.3	HOP= .6
77.112	129.903	96342.6	33927	62415.6	HOP= .6
77.532	129.721	96207.1	31326.7	64880.4	HOP= .6
77.952	129.538	96071.6	28764.5	67307	HOP= .7
78.372	129.355	95936	26240.3	69695.7	HOP= .7
78.78	129.178	95804.4	23758.4	72046	HOP= .7
79.188	129.001	95672.8	21317	74355.8	HOP= .7
79.584	128.828	95545	18918.9	76626.1	HOP= .8

79.98	128.656	95417.2	16565.3	78851.9	HOP= .8
80.376	128.484	95289.4	14257.5	81031.9	HOP= .8
80.772	128.312	95161.7	11995.1	83166.5	HOP= .8
81.156	128.145	95037.8	9779.42	85258.4	HOP= .8
81.528	127.983	94917.8	7613.05	87304.7	HOP= .9
81.912	127.816	94793.9	5497.19	89296.7	HOP= .9
82.284	127.654	94673.8	3432.95	91240.9	HOP= .9
82.644	127.498	94557.7	1418.38	93139.3	HOP= .9
83.004	127.341	94441.5	-540.813	94982.3	HOP= .9
83.364	127.185	94325.4	-2446.67	96772.1	HOP= 1.
83.724	127.028	94209.2	-4298.15	98507.4	HOP= 1.
84.072	126.877	94096.9	-6094.22	100191	HOP= 1.
84.42	126.725	93984.7	-7832.37	101817	HOP= 1.
84.768	126.574	93872.4	-9511.62	103384	HOP= 1.
85.104	126.428	93764	-11134.1	104898	HOP= 1.
85.44	126.282	93655.6	-12695.9	106352	HOP= 1.
85.764	126.141	93551.1	-14196.1	107747	HOP= 1.
86.1	125.995	93442.7	-15637	109080	HOP= 1.
86.424	125.854	93338.1	-17014.5	110353	HOP= 1.
86.736	125.718	93237.5	-18329.5	111567	HOP= 1.
87.048	125.583	93136.8	-19581.3	112718	HOP= 1.
87.36	125.447	93036.2	-20769	113805	HOP= 1.
87.672	125.311	92935.5	-21890.5	114826	HOP= 1.
87.972	125.181	92838.8	-22948.2	115787	HOP= 1.
88.272	125.05	92742	-23938.4	116680	HOP= 1.
88.572	124.92	92645.2	-24862	117507	HOP= 1.
88.872	124.789	92548.4	-25718.5	118267	HOP= 1.
89.16	124.664	92455.6	-26507.3	118963	HOP= 1.
89.436	124.544	92366.5	-27228	119595	HOP= 1.
89.724	124.419	92273.6	-27880.1	120154	HOP= 1.
90	124.299	92184.6	-28463.2	120648	HOP= 1.
90.276	124.179	92095.6	-28978.4	121074	HOP= 1.
90.552	124.059	92006.6	-29422.3	121429	HOP= 1.
90.816	123.944	91921.5	-29796.2	121718	HOP= 1.
91.08	123.829	91836.3	-30099.8	121936	HOP= 1.
91.344	123.715	91751.2	-30334.4	122086	HOP= 1.
91.596	123.605	91669.9	-30496.7	122167	HOP= 1.
91.848	123.495	91588.7	-30589.7	122178	HOP= 1.
92.1	123.386	91507.4	-30611.7	122119	HOP= 1.
92.352	123.276	91426.1	-30562.6	121989	HOP= 1.
92.592	123.172	91348.8	-30442.3	121791	HOP= 1.
92.832	123.067	91271.4	-30252.6	121524	HOP= 1.
93.072	122.963	91194	-29991.7	121186	HOP= 1.
93.312	122.859	91116.6	-29659.8	120776	HOP= 1.
93.54	122.76	91043.1	-29257.1	120300	HOP= 1.
93.768	122.66	90969.6	-28785.3	119755	HOP= 1.
93.984	122.567	90900	-28241.3	119141	HOP= 1.
94.212	122.467	90826.5	-27630.2	118457	HOP= 1.
94.428	122.373	90756.9	-26947.6	117704	HOP= 1.
94.644	122.28	90687.2	-26196.9	116884	HOP= 1.
94.86	122.186	90617.6	-25376.8	115994	HOP= 1.
95.064	122.097	90551.9	-24489.4	115041	HOP= 1.
95.268	122.008	90486.1	-23533.5	114020	HOP= 1.
95.472	121.919	90420.4	-22509.6	112930	HOP= 1.
95.664	121.836	90358.5	-21419.8	111778	HOP= 1.
95.868	121.747	90292.8	-20263	110556	HOP= 1.
96.06	121.664	90230.9	-19041.5	109272	HOP= 1.
96.252	121.58	90169	-17754.3	107923	HOP= .9
96.432	121.502	90111	-16403.6	106515	HOP= .9
96.624	121.419	90049.2	-14988.5	105038	HOP= .9
96.804	121.34	89991.1	-13511.5	103503	HOP= .9
96.972	121.267	89937	-11971.7	101909	HOP= .9

97.152	121.189	89879	-10371.4	100250	HOP= .8
97.32	121.116	89824.9	-8710.03	98534.9	HOP= .8
97.488	121.043	89770.8	-6989.98	96760.8	HOP= .8
97.656	120.97	89716.7	-5210.64	94927.3	HOP= .8
97.824	120.897	89662.6	-3374.51	93037.1	HOP= .7
97.98	120.829	89612.3	-1481.06	91093.4	HOP= .7
98.136	120.761	89562.1	465.612	89096.4	HOP= .7
98.292	120.693	89511.8	2469.06	87042.8	HOP= .7
98.448	120.625	89461.6	4523.57	84938	HOP= .6
98.592	120.563	89415.2	6631.08	82784.1	HOP= .6
98.736	120.5	89368.8	8790.45	80578.4	HOP= .6
98.88	120.438	89322.4	10997.4	78325.1	HOP= .6
99.024	120.375	89276.1	13253.7	76022.3	HOP= .5
99.156	120.317	89233.6	15558.3	73675.3	HOP= .5
99.3	120.255	89187.2	17906.6	71280.6	HOP= .5
99.432	120.197	89144.7	20300.6	68844.1	HOP= .5
99.552	120.145	89106	22738.8	66367.3	HOP= .4
99.684	120.088	89063.5	25216.8	63846.7	HOP= .4
99.804	120.036	89024.9	27736.3	61288.6	HOP= .4
99.924	119.984	88986.3	30294.3	58691.9	HOP= .3
100.044	119.931	88947.6	32891	56056.6	HOP= .3
100.164	119.879	88909	35521.8	53387.2	HOP= .3
100.272	119.832	88874.2	38188.3	50685.9	HOP= .2
100.38	119.785	88839.4	40887.4	47952	HOP= .2
100.488	119.738	88804.7	43619.2	45185.5	HOP= .2
100.596	119.691	88769.9	46379	42390.9	HOP= .1
100.704	119.644	88735.1	49168.3	39566.8	HOP= .1
100.8	119.603	88704.2	51984.1	36720.1	HOP= .1
100.896	119.561	88673.3	54824.7	33848.6	HOP= .8
100.992	119.519	88642.4	57690	30952.4	HOP= .0
101.088	119.477	88611.5	60575.3	28036.2	HOP= .1
101.172	119.441	88584.5	63482.1	25102.3	673.59
101.256	119.404	88557.4	66407.2	22150.3	759.50
101.34	119.368	88530.4	69348.8	19181.6	845.79
101.424	119.331	88503.3	72306.8	16196.5	932.42
101.508	119.295	88476.3	75276.5	13199.8	1019.3
101.58	119.263	88453.1	78259.3	10193.9	1106.4
101.652	119.232	88429.9	81250.2	7179.73	1193.8
101.724	119.201	88406.8	84250.8	4155.98	1281.3
101.796	119.169	88383.6	87257.6	1125.93	1368.8
101.856	119.143	88364.3	90269.1	-1904.88	1456.5
101.916	119.117	88345	93285	-4940.06	1544.1
101.976	119.091	88325.6	96300.5	-7974.83	1631.6

INITIAL DEFLECTION (IN) OF TRAILS = 1.14263

DEFLECTION (IN) OF GUN BARREL AFTER 15 MSEC = .363865E-02
HOP HEIGHT VALUES, IF ANY, ARE IN INCHES
VENUS> LO
M20E96 logged out at 8-APR-1987 13:05:21.37

```
DDDDDDDDDD     0000000000000000000000000000000000000000000000000000     DDDDDDDDDD
DDDDDDDDDD     Digital Equipment Corporation - VAX/VMS Version V4.4      DDDDDDDDDD
DDDDDDDDDD     0000000000000000000000000000000000000000000000000000     DDDDDDDDDD

     M    M   222     000    EEEEE   999     666
     MM  MM  2   2   0   0   E      9   9   6
     M M M      2   0  00   E      9   9   6
     M    M    2    0 0 0   EEEE    9999   6666
     M    M   2     00  0   E          9   6   6
     M    M  2      0   0   E          9   6   6
     M    M  22222   000    EEEEE   999     666


H    H    OOO    PPPP    RRRR    U    U  N    N    222
H    H   O   O   P   P   R   R   U    U  N    N   2   2
H    H   O   O   P   P   R   R   U    U  NN   N       2
HHHHH   O   O   PPPP    RRRR    U    U  N N  N      2
H    H   O   O   P       R R     U    U  N  NN     2
H    H   O   O   P       R  R    U    U  N   N    2
H    H    OOO    P       R   R   UUUUU  N   N   22222

               DDDD     AAA    TTTTT     ;;     222
               D   D   A   A     T       ;;    2   2
               D   D   A   A     T              2
               D   D   A   A     T       ;;    2
               D   D   AAAAA     T       ;;   2
          ..   D   D   A   A     T        ;   2
          ..   DDDD    A   A     T        ;   22222
```

File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOPRUN2.DAT;2 (2061,14,2), last revised on 8-APR-1987 13:15, is a 28 block sequential file owned by UIC [M20,DACKO_SG]. The records are variable length with implied (CR) carriage control. The longest record is 87 bytes.

Job HOPRUN1 (1349) queued to LN on 8-APR-1987 13:17 by user M20E96, UIC [M20,DACKO_SG], under account M22 at priority 100, started on printer _VENUS$TXM6: on 8-APR-1987 13:17 from queue LNSYS.

```
DDDDDDDDDD     0000000000000000000000000000000000000000000000000000     DDDDDDDDDD
DDDDDDDDDD     Digital Equipment Corporation - VAX/VMS Version V4.4      DDDDDDDDDD
DDDDDDDDDD     0000000000000000000000000000000000000000000000000000     DDDDDDDDDD
```

```
A8600 System (VENUS)

Username: M20E96
Password:
Hello...
     Last interactive login on Wednesday,  8-APR-1987 13:04
     Last non-interactive login on Thursday, 26-MAR-1987 08:57
     Last system boot on  5-MAR-1987 22:17:49.02



VENUS>
VENUS> RUN HOP
FIND:  1. MAX. FORCES & MOMENTS
       2. MOMENTS FROM FORCE DATA
(ENTER 1 OR 2):
? 2
FROM:  1. RECOIL.BAS  OR  2. RECOIL.FORT
(ENTER 1 OR 2):
? 2
OUTPUT TO FILE?  1-YES  2-NO
? 2
INPUT TRUNNION HEIGHT, IN. (18.5 TO 31.25)
? 18.5
INPUT HORIZ. DIST. FROM TRUNNION TO
 POINT OF GROUND CONTACT ON SPADE, IN. (24 TO 14.25)
? 24
INPUT SPRING CONSTANT OF EACH TRAIL (LBS/IN)
? 3000
INPUT TRAVERSE ANGLE OF GUN, DEGREES:
? 0
INPUT ELEVATION ANGLE OF GUN, DEGREES:
? 0
INPUT FORWARD (UPWARD) SLOPE OF HILL, DEGREES:
? 0
INPUT SIDE SLOPE OF HILL, DEGREES:
? 0
INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) =  3870.15
WEIGHT OF NON-RECOILING COMPONENTS (LB) =  5029.85
SYSTEM WEIGHT (LB) =  8900
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) =  3000

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) =  163.435
CGY (IN) =  18.2265
CGX (IN) =  43.7133
DEFLECTION OF TRAILS (IN) =  1.14267
MASS MOMENT OF INERTIA (FT-LB-S^2) =  68595.9

SWEEP ANGLE LEFT (DEGREES)                =  0
ELEVATION ANGLE (DEGREES)                 =  0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) =  0
UPWARD SLOPE OF HILL - SIDE    (DEGREES) =  0

ENTER INPUT FORCE DATAFILE NAME, E.G., [.OUTPUT]XXX.LIS
? HOP3.BAT
DATA FILE:  HOP3.BAT


STROKE,       CG -Z,        STABLE        OVERTURN-     SAFETY        WT. AT
```

INCHES	INCHES	MOMENT, FT-LBS	ING MOM., FT-LBS	MOMENT FT-LBS	EA TRAI LBS
36.012	147.776	109600	138852	-29251.6	3099.5
36.036	147.765	109593	139167	-29574.1	3099.3
36.12	147.729	109565	140430	-30864.7	3098.8
36.276	147.661	109515	144094	-34579.2	3098.0
36.528	147.551	109434	151957	-42523.3	3096.8
36.9	147.389	109314	164556	-55242.1	3095.1
37.404	147.17	109151	180827	-71676.2	3092.9
38.004	146.909	108958	197277	-88319.1	3090.0
38.7	146.607	108733	213319	-104586	3086.2
39.468	146.273	108486	227467	-118981	3081.2
40.296	145.913	108219	239057	-130839	3075.0
41.148	145.542	107944	247408	-139465	3067.3
42.048	145.151	107654	234313	-126660	3058.1
42.948	144.759	107363	233947	-126584	3047.3
43.848	144.368	107073	233528	-126455	3035.0
44.76	143.972	106779	233057	-126278	3021.2
45.66	143.58	106489	232532	-126044	3005.9
46.572	143.184	106195	231955	-125760	2989.1
47.472	142.792	105904	231324	-125420	2970.9
48.372	142.401	105614	230640	-125026	2951.1
49.26	142.015	105328	229902	-124575	2929.7
50.148	141.629	105041	229111	-124070	2906.9
51.036	141.242	104755	228266	-123511	2882.6
51.924	140.856	104468	227367	-122899	2856.7
52.8	140.475	104186	226415	-122229	2829.3
53.676	140.094	103903	225409	-121505	2800.4
54.54	139.719	103625	224349	-120724	2770.0
55.404	139.343	103346	223234	-119888	2738.0
56.256	138.972	103071	222068	-118996	2704.6
57.108	138.602	102796	220847	-118051	2669.6
57.948	138.237	102526	219573	-117047	2633.2
58.788	137.871	102255	218246	-115992	2595.2
59.616	137.511	101988	216866	-114878	2555.7
60.444	137.151	101721	215433	-113712	2514.8
61.26	136.797	101457	213949	-112492	2472.4
62.064	136.447	101198	212412	-111214	2428.5
62.868	136.097	100939	210823	-109884	2383.1
63.66	135.753	100683	209183	-108500	2336.3
64.452	135.408	100428	207492	-107064	2288.1
65.232	135.069	100176	205751	-105575	2238.4
66	134.735	99928.6	203960	-104031	2187.4
66.768	134.401	99680.9	202118	-102437	2134.9
67.524	134.073	99437.1	200228	-100791	2081.0
68.28	133.744	99193.3	198291	-99097.4	2025.8
69.024	133.42	98953.3	196304	-97350.4	1969.2
69.756	133.102	98717.2	194271	-95553.9	1911.3
70.488	132.784	98481.1	192191	-93709.5	1852.1
71.208	132.471	98248.9	190064	-91815.5	1791.6
71.928	132.158	98016.6	187893	-89876.5	1729.8
72.624	131.855	97792.2	185678	-87885.5	1666.7
73.332	131.547	97563.8	183419	-85854.9	1602.5
74.016	131.25	97343.1	181117	-83774	1537.0
74.7	130.952	97122.5	178774	-81651.2	1470.3
75.372	130.66	96905.8	176389	-79483.6	1402.5
76.044	130.368	96689	173965	-77276.1	1333.6
76.704	130.081	96476.1	171500	-75024	1263.5
77.352	129.799	96267.1	168999	-72731.6	1192.4
78	129.517	96058.1	166459	-70400.6	1120.2
78.636	129.241	95852.9	163884	-68031.1	1047.0

79.26	128.969	95651.7	161273	-65621.3	972.83
79.884	128.698	95450.4	158628	-63177.6	897.68
80.496	128.432	95253	155950	-60697.2	821.60
81.096	128.171	95059.4	153241	-58181.3	744.62
81.696	127.91	94865.9	150501	-55635.1	666.79
82.284	127.654	94676.2	147732	-53055.6	588.12
82.86	127.404	94490.4	144935	-50444.3	HOP= .2
83.436	127.153	94304.6	142109	-47804.7	HOP= .5
84	126.908	94122.6	139260	-45137.3	HOP= .0
84.552	126.668	93944.5	136385	-42440.2	HOP= .1
85.104	126.428	93766.4	133488	-39721.9	HOP= .1
85.644	126.193	93592.2	130569	-36976.6	HOP= .1
86.172	125.964	93421.9	127629	-34207.3	HOP= .2
86.7	125.734	93251.5	124671	-31419.3	HOP= .2
87.216	125.51	93085.1	121695	-28610.1	HOP= .2
87.732	125.285	92918.6	118704	-25785	HOP= .3
88.224	125.071	92759.9	115698	-22937.7	HOP= .3
88.728	124.852	92597.2	112679	-20081.3	HOP= .3
89.208	124.643	92442.4	109648	-17205.7	HOP= .4
89.688	124.435	92287.5	106606	-14318.5	HOP= .4
90.156	124.231	92136.5	103557	-11420.6	HOP= .4
90.612	124.033	91989.3	100500	-8510.32	HOP= .5
91.068	123.835	91842.2	97436.9	-5594.67	HOP= .5
91.512	123.641	91698.9	94371.8	-2672.92	HOP= .6
91.956	123.448	91555.7	91303	252.656	HOP= .6
92.376	123.266	91420.1	88233.5	3186.6	HOP= .6
92.808	123.078	91280.7	85165	6115.74	HOP= .7
93.216	122.9	91149.1	82099	9050.08	HOP= .7
93.624	122.723	91017.4	79035.6	11981.8	HOP= .7
94.02	122.551	90889.6	75979.5	14910.1	HOP= .8
94.404	122.384	90765.7	72930.8	17834.9	HOP= .8
94.788	122.217	90641.7	69889.5	20752.2	HOP= .8
95.16	122.055	90521.7	66858.9	23662.7	HOP= .9
95.532	121.893	90401.6	63842.1	26559.5	HOP= .9
95.892	121.737	90285.4	60837.7	29447.7	HOP= .9
96.24	121.585	90173.1	57848.8	32324.2	HOP= 1.
96.576	121.439	90064.6	54877.1	35187.5	HOP= 1.
96.912	121.293	89956.2	51924.2	38031.9	HOP= 1.
97.236	121.152	89851.6	48991.8	40859.8	HOP= 1.
97.56	121.012	89747	46081.3	43665.7	HOP= 1.
97.86	120.881	89650.1	43193	46457.1	HOP= 1.
98.172	120.745	89549.4	40331.5	49217.9	HOP= 1.
98.46	120.62	89456.4	37495.3	51961.1	HOP= 1.
98.748	120.495	89363.5	34689.1	54674.3	HOP= 1.
99.024	120.375	89274.3	31911.4	57362.9	HOP= 1.
99.288	120.26	89189.1	29165.4	60023.8	HOP= 1.
99.552	120.145	89103.9	26452.4	62651.4	HOP= 1.
99.804	120.036	89022.5	23774.2	65248.3	HOP= 1.
100.056	119.926	88941.1	21132.2	67808.9	HOP= 1.
100.296	119.822	88863.6	18527.9	70335.7	HOP= 1.
100.524	119.723	88790	15962.9	72827.1	HOP= 1.
100.74	119.629	88720.3	13437.1	75283.2	HOP= 1.
100.956	119.535	88650.5	10954.9	77695.6	HOP= 1.
101.16	119.446	88584.6	8514.79	80069.8	HOP= 1.
101.364	119.357	88518.7	6121.23	82397.5	HOP= 1.
101.544	119.279	88460.6	3772.52	84688.1	HOP= 1.
101.736	119.196	88398.6	1471.61	86926.9	HOP= 1.
101.904	119.123	88344.3	-780.198	89124.5	HOP= 1.
102.072	119.049	88290	-2981.6	91271.6	HOP= 1.
102.228	118.982	88239.6	-5131.27	93370.9	HOP= 1.
102.372	118.919	88193.1	-7227.98	95421.1	HOP= 1.
102.516	118.856	88146.6	-9272.04	97418.6	HOP= 1.

102.648	118.799	88103.9	-11259.1	99363	HOP= 1.
102.78	118.742	88061.3	-13191.2	101252	HOP= 1.
102.9	118.689	88022.5	-15063.9	103086	HOP= 1.
103.008	118.642	87987.6	-16879.4	104867	HOP= 1.
103.104	118.601	87956.5	-18635	106592	HOP= 1.
103.2	118.559	87925.5	-20329.6	108255	HOP= 1.
103.284	118.522	87898.3	-21962.3	109861	HOP= 1.
103.356	118.491	87875	-23532	111407	HOP= 1.
103.428	118.46	87851.7	-25037.9	112890	HOP= 1.
103.488	118.434	87832.3	-26479	114311	HOP= 1.
103.548	118.408	87812.9	-27856	115669	HOP= 2.
103.596	118.387	87797.4	-29165	116962	HOP= 2.
103.632	118.371	87785.7	-30408.3	118194	HOP= 2.
103.656	118.361	87777.9	-31582.1	119360	HOP= 2.
103.68	118.35	87770.1	-32688.8	120459	HOP= 2.
103.692	118.345	87766.2	-33726.1	121492	HOP= 2.
103.692	118.345	87766.2	-161963	249729	HOP= 2.
103.692	118.345	87766.1	-162823	250589	HOP= 2.
103.692	118.345	87766.1	-163538	251304	HOP= 2.
103.692	118.345	87766.1	-164108	251874	HOP= 2.
103.692	118.345	87766	-164533	252299	HOP= 2.
103.692	118.345	87766	-164811	252578	HOP= 2.
103.692	118.345	87766	-164944	252710	HOP= 2.

INITIAL DEFLECTION (IN) OF TRAILS = 1.03318

DEFLECTION (IN) OF GUN BARREL AFTER 15 MSEC = .026204
HOP HEIGHT VALUES, IF ANY, ARE IN INCHES
VENUS> LO
M20E96 logged out at 8-APR-1987 13:06:53.62

```
EEEEEEEEEE    0000000000000000000000000000000000000000000000000000    EEEEEEEEEE
EEEEEEEEEE    Digital Equipment Corporation - VAX/VMS Version V4.4     EEEEEEEEEE
EEEEEEEEEE    0000000000000000000000000000000000000000000000000000    EEEEEEEEEE
```

43

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     M    M    222      000    EEEEE    999     666
     MM  MM   2   2   0   0   E       9   9   6
     M M M       2   0  00   E       9   9   6
     M    M     2    0 0 0   EEEE     9999   6666
     M    M    2     00  0   E            9   6   6
     M    M   2      0   0   E            9   6   6
     M    M   22222   000    EEEEE    999     666


H    H    OOO    PPPP    RRRR    U    U  N    N    333
H    H   O   O   P   P   R   R   U    U  N    N   3   3
H    H   O   O   P   P   R   R   U    U  NN   N       3
HHHHH    O   O   PPPP    RRRR    U    U  N N  N      3
H    H   O   O   P       R R     U    U  N  NN       3
H    H   O   O   P       R  R    U    U  N    N   3   3
H    H    OOO    P       R   R    UUUUU  N    N    333

              DDDD     AAA    TTTTT     ;;     222
              D   D   A   A     T       ;;    2   2
              D   D   A   A     T             2
              D   D   A   A     T       ;;      2
              D   D   AAAAA     T       ;;     2
         ..   D   D   A   A     T        ;    2
         ..   DDDD    A   A     T        ;    22222
```

```
File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOPRUN3.DAT;2 (2378,38,2), last revised on
8-APR-1987 13:16, is a 42 block sequential file owned by UIC [M20,DACKO_SG].
The records are variable length with implied (CR) carriage control.  The
longest record is 87 bytes.

Job HOPRUN1 (1349) queued to LN on 8-APR-1987 13:17 by user M20E96, UIC
[M20,DACKO_SG], under account M22 at priority 100, started on printer
_VENUS$TXM6: on 8-APR-1987 13:17 from queue LNSYS.

EEEEEEEEEE    0000000000000000000000000000000000000000000000000000    EEEEEEEEEE
EEEEEEEEEE    Digital Equipment Corporation - VAX/VMS Version V4.4     EEEEEEEEEE
EEEEEEEEEE    0000000000000000000000000000000000000000000000000000    EEEEEEEEEE
```

```
A8600 System (VENUS)

Username: M20E96
Password:
Hello...
     Last interactive login on Wednesday,  8-APR-1987 13:06
     Last non-interactive login on Thursday, 26-MAR-1987 08:57
     Last system boot on  5-MAR-1987 22:17:49.02



THE DATE AND TIME IS
   8-APR-1987 13:07:23
VENUS> RUN HOP
FIND:  1. MAX. FORCES & MOMENTS
       2. MOMENTS FROM FORCE DATA
(ENTER 1 OR 2):
? 2
FROM:  1. RECOIL.BAS  OR  2. RECOIL.FORT
(ENTER 1 OR 2):
? 2
OUTPUT TO FILE?  1-YES  2-NO
? 2
INPUT TRUNNION HEIGHT, IN. (18.5 TO 31.25)
? 31.25
INPUT HORIZ. DIST. FROM TRUNNION TO
 POINT OF GROUND CONTACT ON SPADE, IN. (24 TO 14.25)
? 14.25
INPUT SPRING CONSTANT OF EACH TRAIL (LBS/IN)
? 3000
INPUT TRAVERSE ANGLE OF GUN, DEGREES:
? 0
INPUT ELEVATION ANGLE OF GUN, DEGREES:
? 0
INPUT FORWARD (UPWARD) SLOPE OF HILL, DEGREES:
? 0
INPUT SIDE SLOPE OF HILL, DEGREES:
? 0
INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) =  3870.15
WEIGHT OF NON-RECOILING COMPONENTS (LB) =  5029.85
SYSTEM WEIGHT (LB) =  8900
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) =  3000

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) =  153.685
CGY (IN) =  30.9765
CGX (IN) =  43.7133
DEFLECTION OF TRAILS (IN) =  1.0745
MASS MOMENT OF INERTIA (FT-LB-S^2) =  63865.3

SWEEP ANGLE LEFT (DEGREES)                 =  0
ELEVATION ANGLE (DEGREES)                  =  0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) =  0
UPWARD SLOPE OF HILL - SIDE    (DEGREES) =  0

ENTER INPUT FORCE DATAFILE NAME, E.G., [.OUTPUT]XXX.LIS
? HOP3.DAT
DATA FILE:  HOP3.DAT
```

STROKE, INCHES	CG -Z, INCHES	STABLE MOMENT, FT-LBS	OVERTURN-ING MOM., FT-LBS	SAFETY MOMENT FT-LBS	WT. AT EA TRAI LBS
.012	153.68	113979	127000	-13020.8	3223.3
.048	153.665	113968	127001	-13032.8	3223.3
.12	153.633	113945	127002	-13056.9	3223.1
.276	153.565	113894	127037	-13142.6	3222.8
.54	153.451	113809	127175	-13365.3	3222.3
.924	153.284	113685	127557	-13872.1	3221.7
1.428	153.064	113523	128396	-14873.6	3221.0
2.052	152.793	113322	129931	-16609.3	3220.1
2.772	152.48	113089	132387	-19297.4	3219.1
3.552	152.141	112838	135964	-23126.1	3217.9
4.404	151.77	112563	140820	-28256.8	3216.5
5.304	151.379	112273	147078	-34805.3	3214.8
6.24	150.972	111971	154833	-42861.7	3212.8
7.2	150.554	111661	164055	-52393.6	3210.4
8.16	150.137	111352	174666	-63314.3	3207.5
9.132	149.714	111038	186675	-75636.8	3204.0
10.104	149.292	110725	200080	-89355.6	3199.7
11.088	148.864	110407	214874	-104467	3194.6
12.06	148.441	110094	231046	-120952	3188.5
13.044	148.013	109776	248298	-138521	3181.2
14.016	147.591	109463	265427	-155964	3172.5
15	147.163	109146	281061	-171916	3162.2
15.972	146.74	108832	293841	-185009	3150.1
16.944	146.317	108519	302448	-193929	3136.1
17.904	145.9	108209	305611	-197402	3120.0
18.864	145.482	107899	304999	-197099	3101.8
19.824	145.065	107590	304278	-196688	3081.4
20.772	144.653	107284	303480	-196195	3058.8
21.72	144.24	106978	302604	-195625	3034.0
22.656	143.833	106676	301650	-194974	3007.0
23.592	143.426	106375	300619	-194244	2977.8
24.516	143.025	106077	299509	-193433	2946.4
25.44	142.623	105779	298322	-192543	2912.8
26.352	142.226	105484	297056	-191572	2877
27.264	141.83	105190	295712	-190522	2838.9
28.164	141.438	104900	294290	-189390	2798.6
29.052	141.052	104614	292789	-188176	2756.2
29.94	140.666	104327	291211	-186883	2711.5
30.828	140.28	104041	289554	-185513	2664.6
31.692	139.904	103762	287820	-184057	2615.5
32.568	139.523	103480	286008	-182528	2564.2
33.42	139.153	103205	284118	-180913	2510.7
34.272	138.782	102930	282152	-179222	2455.0
35.124	138.412	102655	280109	-177453	2397.2
35.964	138.046	102384	277989	-175605	2337.2
36.792	137.686	102117	275793	-173676	2275.0
37.62	137.326	101850	273522	-171672	2210.7
38.436	136.972	101587	271176	-169589	2144.3
39.24	136.622	101328	268743	-167415	2075.8
40.044	136.272	101068	266045	-164976	2005.2
40.836	135.928	100813	263042	-162229	1932.5
41.628	135.583	100558	259759	-159201	1857.7
42.408	135.244	100306	256217	-155911	1781.0
43.176	134.91	100058	252440	-152382	1702.2
43.944	134.576	99810.5	248451	-148640	1621.5
44.7	134.248	99566.6	244272	-144705	1538.9
45.456	133.919	99322.8	239917	-140594	1454.4

46.2	133.595	99082.8	235413	-136331	1368.0
46.932	133.277	98846.7	230774	-131927	1279.9
47.664	132.959	98610.6	226019	-127408	1190.0
48.396	132.64	98374.4	221165	-122790	1098.5
49.104	132.333	98146.1	216227	-118081	1005.3
49.812	132.025	97917.7	211222	-113305	910.52
50.52	131.717	97689.3	206167	-108477	814.21
51.216	131.414	97464.8	201072	-103608	716.43
51.9	131.117	97244.1	195951	-98707.4	617.25
52.584	130.819	97023.4	190819	-93796	HOP= .2
53.256	130.527	96806.6	185686	-88879.5	HOP= .0
53.928	130.235	96589.8	180567	-83976.9	HOP= .1
54.588	129.948	96376.9	175450	-79073.4	HOP= .1
55.236	129.666	96167.8	170308	-74140.2	HOP= .1
55.884	129.384	95958.8	165142	-69183.1	HOP= .2
56.532	129.103	95749.7	159957	-64207	HOP= .2
57.168	128.826	95544.5	154752	-59207.9	HOP= .3
57.804	128.549	95339.3	149531	-54191.8	HOP= .3
58.416	128.283	95141.8	144295	-49153.3	HOP= .4
59.04	128.012	94940.5	139050	-44109.1	HOP= .4
59.652	127.746	94743	133792	-39048.5	HOP= .5
60.252	127.485	94549.4	128529	-33979.2	HOP= .5
60.852	127.224	94355.8	123261	-28904.9	HOP= .5
61.452	126.963	94162.2	117990	-23827.9	HOP= .6
62.04	126.707	93972.5	112717	-18744.5	HOP= .6
62.616	126.457	93786.6	107449	-13662.1	HOP= .7
63.192	126.206	93600.7	102185	-8584.67	HOP= .7
63.756	125.961	93418.7	96926.9	-3508.18	HOP= .8
64.32	125.716	93236.7	91678.3	1558.33	HOP= .8
64.884	125.471	93054.6	86442.3	6612.34	HOP= .9
65.436	125.231	92876.5	81221.4	11655.1	HOP= .9
65.988	124.991	92698.3	76015.6	16682.8	HOP= 1.
66.528	124.756	92524.1	70830	21694.1	HOP= 1.
67.056	124.526	92353.6	65664.6	26689	HOP= 1.
67.584	124.297	92183.2	60527.3	31655.9	HOP= 1.
68.112	124.067	92012.8	55412.9	36599.9	HOP= 1.
68.628	123.843	91846.2	50329.1	41517.1	HOP= 1.
69.144	123.618	91679.7	45278.6	46401.1	HOP= 1.
69.66	123.394	91513.1	40261.4	51251.8	HOP= 1.
70.164	123.175	91350.4	35280	56070.4	HOP= 1.
70.656	122.961	91191.6	30339.7	60851.9	HOP= 1.
71.148	122.747	91032.8	25440.5	65592.3	HOP= 1.
71.64	122.533	90874	20587.6	70286.4	HOP= 1.
72.12	122.324	90719	15778.2	74940.8	HOP= 1.
72.6	122.115	90564.1	11020.3	79543.8	HOP= 1.
73.068	121.912	90413	6313.75	84099.3	HOP= 1.
73.536	121.708	90261.9	1661.09	88600.8	HOP= 1.
74.004	121.505	90110.8	-2932.55	93043.4	HOP= 1.
74.46	121.307	89963.6	-7469.85	97433.5	HOP= 1.
74.916	121.108	89816.4	-11943.1	101760	HOP= 1.
75.36	120.915	89673.1	-16355.1	106028	HOP= 1.
75.804	120.722	89529.7	-20698.2	110228	HOP= 1.
76.248	120.529	89386.4	-24975.1	114361	HOP= 1.
76.68	120.341	89246.9	-29180.8	118428	HOP= 1.
77.112	120.153	89107.5	-33310.4	122418	HOP= 1.
77.532	119.971	88971.9	-37366.7	126339	HOP= 2.
77.952	119.788	88836.3	-41344.9	130181	HOP= 2.
78.372	119.605	88700.7	-45245.2	133946	HOP= 2.
78.78	119.428	88569	-49060.2	137629	HOP= 2.
79.188	119.251	88437.2	-52792.9	141230	HOP= 2.
79.584	119.078	88309.4	-56438.5	144748	HOP= 2.
79.98	118.906	88181.6	-59995	148177	HOP= 2.

80.376	118.734	88053.7	-63460.1	151514	HOP= 2.
80.772	118.562	87925.9	-66834.5	154760	HOP= 2.
81.156	118.395	87801.9	-70116.1	157918	HOP= 2.
81.528	118.233	87681.9	-73300.4	160982	HOP= 2.
81.912	118.066	87557.9	-76385.5	163943	HOP= 2.
82.284	117.904	87437.8	-79369.5	166807	HOP= 2.
82.644	117.748	87321.6	-82255.8	169577	HOP= 2.
83.004	117.591	87205.4	-85034.9	172240	HOP= 2.
83.364	117.435	87089.2	-87710.1	174799	HOP= 2.
83.724	117.278	86973	-90280	177253	HOP= 2.
84.072	117.127	86860.7	-92742.7	179603	HOP= 2.
84.42	116.975	86748.4	-95094.3	181843	HOP= 2.
84.768	116.824	86636.1	-97333.2	183969	HOP= 2.
85.104	116.678	86527.7	-99463.2	185991	HOP= 2.
85.44	116.532	86419.3	-101478	187897	HOP= 2.
85.764	116.391	86314.7	-103375	189690	HOP= 2.
86.1	116.245	86206.3	-105160	191367	HOP= 2.
86.424	116.104	86101.8	-106826	192928	HOP= 2.
86.736	115.968	86001.1	-108374	194375	HOP= 2.
87.048	115.833	85900.4	-109803	195704	HOP= 2.
87.36	115.697	85799.8	-111113	196912	HOP= 2.
87.672	115.561	85699.2	-112299	197998	HOP= 2.
87.972	115.431	85602.4	-113366	198968	HOP= 2.
88.272	115.3	85505.6	-114308	199814	HOP= 2.
88.572	115.17	85408.9	-115127	200536	HOP= 2.
88.872	115.039	85312.1	-115823	201135	HOP= 2.
89.16	114.914	85219.3	-116394	201613	HOP= 2.
89.436	114.794	85130.3	-116840	201971	HOP= 2.
89.724	114.669	85037.4	-117162	202199	HOP= 2.
90	114.549	84948.4	-117358	202306	HOP= 2.
90.276	114.429	84859.5	-117430	202290	HOP= 2.
90.552	114.309	84770.5	-117374	202145	HOP= 2.
90.816	114.194	84685.4	-117192	201878	HOP= 2.
91.08	114.079	84600.3	-116884	201484	HOP= 2.
91.344	113.965	84515.2	-116452	200967	HOP= 2.
91.596	113.855	84434	-115892	200326	HOP= 2.
91.848	113.745	84352.8	-115208	199561	HOP= 2.
92.1	113.636	84271.6	-114399	198671	HOP= 2.
92.352	113.526	84190.4	-113464	197655	HOP= 2.
92.592	113.422	84113.1	-112405	196518	HOP= 2.
92.832	113.317	84035.8	-111224	195260	HOP= 2.
93.072	113.213	83958.5	-109919	193877	HOP= 2.
93.312	113.109	83881.2	-108491	192372	HOP= 2.
93.54	113.01	83807.8	-106940	190748	HOP= 2.
93.768	112.91	83734.4	-105270	189004	HOP= 2.
93.984	112.817	83664.8	-103477	187142	HOP= 2.
94.212	112.717	83591.4	-101569	185160	HOP= 2.
94.428	112.623	83521.9	-99539.6	183061	HOP= 2.
94.644	112.53	83452.4	-97395	180847	HOP= 2.
94.86	112.436	83382.8	-95133.8	178517	HOP= 2.
95.064	112.347	83317.2	-92759.8	176077	HOP= 2.
95.268	112.258	83251.5	-90271.8	173523	HOP= 2.
95.472	112.169	83185.9	-87671	170857	HOP= 2.
95.664	112.086	83124.1	-84961.6	168086	HOP= 2.
95.868	111.997	83058.5	-82142.5	165201	HOP= 2.
96.06	111.914	82996.7	-79217.9	162215	HOP= 2.
96.252	111.83	82934.9	-76186.9	159122	HOP= 2.
96.432	111.752	82877	-73053.7	155931	HOP= 1.
96.624	111.669	82815.3	-69817.6	152633	HOP= 1.
96.804	111.59	82757.4	-66483.1	149240	HOP= 1.
96.972	111.517	82703.4	-63049.4	145753	HOP= 1.
97.152	111.439	82645.5	-59521.2	142167	HOP= 1.

97.32	111.366	82591.5	-55898	138489	HOP= 1.
97.488	111.293	82537.4	-52184.4	134722	HOP= 1.
97.656	111.22	82483.4	-48380.1	130864	HOP= 1.
97.824	111.147	82429.4	-44489.9	126919	HOP= 1.
97.98	111.079	82379.3	-40513.5	122893	HOP= 1.
98.136	111.011	82329.1	-36458.4	118788	HOP= 1.
98.292	110.943	82279	-32319.4	114598	HOP= 1.
98.448	110.875	82228.8	-28106.5	110335	HOP= 1.
98.592	110.813	82182.5	-23817.3	106000	HOP= 1.
98.736	110.75	82136.3	-19454.1	101590	HOP= 1.
98.88	110.688	82090	-15024.9	97114.9	HOP= 1.
99.024	110.625	82043.7	-10527.2	92570.9	HOP= 1.
99.156	110.568	82001.3	-5963.55	87964.8	HOP= 1.
99.3	110.505	81955	-1342.05	83297	HOP= 1.
99.432	110.447	81912.6	3339.78	78572.8	HOP= 1.
99.552	110.395	81874	8079.05	73795	HOP= .9
99.684	110.338	81831.6	12867.7	68963.9	HOP= .8
99.804	110.286	81793	17708	64085	HOP= .8
99.924	110.234	81754.5	22594.4	59160.1	HOP= .7
100.044	110.181	81715.9	27526.4	54189.5	HOP= .7
100.164	110.129	81677.3	32496	49181.3	HOP= .6
100.272	110.082	81642.6	37505.2	44137.4	HOP= .5
100.38	110.035	81607.9	42548.4	39059.5	HOP= .5
100.488	109.988	81573.2	47625	33948.2	HOP= .4
100.596	109.941	81538.5	52726.8	28811.7	HOP= .4
100.704	109.894	81503.8	57855.7	23648.1	HOP= .3
100.8	109.853	81472.9	63006	18466.9	HOP= .2
100.896	109.811	81442	68174.5	13267.5	HOP= .2
100.992	109.769	81411.2	73360.7	8050.46	HOP= .1
101.088	109.727	81380.3	78556.1	2824.23	HOP= .1
101.172	109.691	81353.3	83762.6	-2409.32	HOP= .4
101.256	109.654	81326.3	88974.5	-7648.22	626.9
101.34	109.618	81299.3	94188.5	-12889.2	779.66
101.424	109.581	81272.3	99403.9	-18131.7	932.25
101.508	109.545	81245.2	104612	-23367.1	1084.5
101.58	109.513	81222.1	109816	-28593.7	1236.5
101.652	109.482	81198.9	115006	-33806.7	1388
101.724	109.451	81175.7	120184	-39008.1	1538.9
101.796	109.42	81152.6	125345	-44192.2	1689.2
101.856	109.393	81133.3	130485	-49351.8	1838.8
101.916	109.367	81114	135604	-54490.2	1987.5
101.976	109.341	81094.6	140694	-59598.9	2135.4

INITIAL DEFLECTION (IN) OF TRAILS = 1.07446

DEFLECTION (IN) OF GUN BARREL AFTER 15 MSEC = .648644E-02
HOP HEIGHT VALUES, IF ANY, ARE IN INCHES
VENUS> LO
M20E96 logged out at 8-APR-1987 13:08:08.04

```
FFFFFFFFFF    0000000000000000000000000000000000000000000000000000    FFFFFFFFFF
FFFFFFFFFF    Digital Equipment Corporation - VAX/VMS Version V4.4     FFFFFFFFFF
FFFFFFFFFF    0000000000000000000000000000000000000000000000000000    FFFFFFFFFF
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```
     M    M    222     000    EEEEE    999     666
     MM  MM   2   2   0   0   E       9   9   6
     M M M        2   0  00   E       9   9   6
     M    M      2    0 0 0   EEEE     9999   6666
     M    M     2     00  0   E           9   6   6
     M    M    2      0   0   E           9   6   6
     M    M   22222    000    EEEEE    999     666

 H    H    OOO    PPPP    RRRR    U    U  N    N  4   4
 H    H   O   O   P   P   R   R   U    U  N    N  4   4
 H    H   O   O   P   P   R   R   U    U  NN   N  4   4
 HHHHH   O   O   PPPP    RRRR    U    U  N N  N  44444
 H    H   O   O   P       R R     U    U  N  NN      4
 H    H   O   O   P       R  R    U    U  N   N      4
 H    H    OOO    P       R   R    UUUUU  N   N      4

              DDDD     AAA    TTTTT     ;;     222
              D   D   A   A     T       ;;    2   2
              D   D   A   A     T             2
              D   D   A   A     T       ;;      2
              D   D   AAAAA     T       ;;     2
         ..   D   D   A   A     T        ;     2
         ..   DDDD    A   A     T        ;     22222
```

```
File _HSC000$DUA9:[M20.DACKO_SG.VMS]HOPRUN4.DAT;2 (2393,16,2), last revised on
8-APR-1987 13:16, is a 28 block sequential file owned by UIC [M20,DACKO_SG].
The records are variable length with implied (CR) carriage control.  The
longest record is 87 bytes.

Job HOPRUN1 (1349) queued to LN on 8-APR-1987 13:17 by user M20E96, UIC
[M20,DACKO_SG], under account M22 at priority 100, started on printer
_VENUS$TXM6: on 8-APR-1987 13:18 from queue LNSYS.

FFFFFFFFFF    0000000000000000000000000000000000000000000000000000    FFFFFFFFFF
FFFFFFFFFF    Digital Equipment Corporation - VAX/VMS Version V4.4     FFFFFFFFFF
FFFFFFFFFF    0000000000000000000000000000000000000000000000000000    FFFFFFFFFF
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```
A8600 System (VENUS)

Username: M20E96
Password:
Hello...
    Last interactive login on Wednesday,  8-APR-1987 13:08
    Last non-interactive login on Thursday, 26-MAR-1987 08:57
    Last system boot on  5-MAR-1987 22:17:49.02



THE DATE AND TIME IS
   8-APR-1987 13:09:07
VENUS> RUN HOP
FIND:  1. MAX. FORCES & MOMENTS
       2. MOMENTS FROM FORCE DATA
(ENTER 1 OR 2):
? 2
FROM:  1. RECOIL.BAS  OR  2. RECOIL.FORT
(ENTER 1 OR 2):
? 2
OUTPUT TO FILE?  1-YES  2-NO
? 2
INPUT TRUNNION HEIGHT, IN. (18.5 TO 31.25)
? 31.25
INPUT HORIZ. DIST. FROM TRUNNION TO
 POINT OF GROUND CONTACT ON SPADE, IN. (24 TO 14.25)
? 14.25
INPUT SPRING CONSTANT OF EACH TRAIL (LBS/IN)
? 3000
INPUT TRAVERSE ANGLE OF GUN, DEGREES:
? 0
INPUT ELEVATION ANGLE OF GUN, DEGREES:
? 0
INPUT FORWARD (UPWARD) SLOPE OF HILL, DEGREES:
? 0
INPUT SIDE SLOPE OF HILL, DEGREES:
? 0
INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) =  3870.15
WEIGHT OF NON-RECOILING COMPONENTS (LB) =  5029.85
SYSTEM WEIGHT (LB) =  8900
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) =  3000

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) =  153.685
CGY (IN) =  30.9765
CGX (IN) =  43.7133
DEFLECTION OF TRAILS (IN) =  1.0745
MASS MOMENT OF INERTIA (FT-LB-S^2) =  63865.3

SWEEP ANGLE LEFT (DEGREES)                =  0
ELEVATION ANGLE (DEGREES)                 =  0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) =  0
UPWARD SLOPE OF HILL - SIDE    (DEGREES) =  0

ENTER INPUT FORCE DATAFILE NAME, E.G., [.OUTPUT]XXX.LIS
? HOP3.BAT
DATA FILE:  HOP3.BAT
```

STROKE, INCHES	CG -Z, INCHES	STABLE MOMENT, FT-LBS	OVERTURNING MOM., FT-LBS	SAFETY MOMENT FT-LBS	WT. AT EA TRAI LBS
36.012	138.026	102369	151780	-49411.5	2895.0
36.036	138.015	102361	152311	-49950.2	2894.7
36.12	137.979	102334	154443	-52109.3	2893.8
36.276	137.911	102284	160629	-58345	2892.3
36.528	137.801	102203	173905	-71702.5	2890.0
36.9	137.639	102083	195179	-93096.6	2887.0
37.404	137.42	101920	222655	-120734	2883.0
38.004	137.159	101727	250427	-148701	2877.7
38.7	136.857	101502	277508	-176006	2870.7
39.468	136.523	101254	301383	-200129	2861.7
40.296	136.163	100987	320933	-219946	2850.4
41.148	135.792	100713	335005	-234292	2836.4
42.048	135.401	100422	312843	-212421	2819.6
42.948	135.009	100132	312176	-212044	2800
43.848	134.618	99841.8	311413	-211572	2777.6
44.76	134.222	99547.7	310556	-211008	2752.6
45.66	133.83	99257.4	309602	-210345	2724.9
46.572	133.434	98963.3	308553	-209590	2694.5
47.472	133.042	98673	307408	-208735	2661.3
48.372	132.651	98382.7	306167	-207784	2625.4
49.26	132.265	98096.3	304829	-206733	2586.8
50.148	131.879	97809.9	303396	-205586	2545.5
51.036	131.492	97523.5	301866	-204342	2501.5
51.924	131.106	97237.2	300240	-203003	2454.7
52.8	130.725	96954.6	298518	-201564	2405.2
53.676	130.344	96672.1	296701	-200028	2353.0
54.54	129.969	96393.4	294787	-198394	2298.1
55.404	129.593	96114.8	292776	-196661	2240.5
56.256	129.223	95840	290673	-194833	2180.2
57.108	128.852	95565.2	288475	-192909	2117.3
57.948	128.487	95294.3	286180	-190886	2051.6
58.788	128.121	95023.4	283794	-188771	1983.4
59.616	127.761	94756.3	281313	-186557	1912.5
60.444	127.401	94489.2	278739	-184250	1838.9
61.26	127.047	94226	276076	-181850	1762.8
62.064	126.697	93966.7	273320	-179353	1684.1
62.868	126.347	93707.4	270474	-176766	1602.9
63.66	126.003	93451.9	267538	-174086	1519.1
64.452	125.659	93196.5	264514	-171317	1432.8
65.232	125.319	92944.9	261402	-168457	1344.1
66	124.985	92697.2	258204	-165507	1252.9
66.768	124.651	92449.4	254919	-162469	1159.3
67.524	124.323	92205.6	251551	-159346	1063.3
68.28	123.994	91961.7	248101	-156140	965.00
69.024	123.67	91721.7	244567	-152845	864.37
69.756	123.352	91485.6	240955	-149470	761.45
70.488	123.034	91249.5	237262	-146013	656.31
71.208	122.721	91017.2	233492	-142475	548.98
71.928	122.408	90784.9	229645	-138860	HOP= .3
72.624	122.105	90560.4	225725	-135164	HOP= .7
73.332	121.797	90332	221732	-131400	HOP= .1
74.016	121.5	90111.3	217668	-127556	HOP= .1
74.7	121.202	89890.7	213535	-123644	HOP= .2
75.372	120.91	89673.9	209334	-119660	HOP= .2
76.044	120.618	89457.1	205068	-115611	HOP= .3
76.704	120.331	89244.1	200736	-111492	HOP= .3
77.352	120.049	89035	196345	-107310	HOP= .4

78	119.767	88826	191892	-103066	HOP= .4
78.636	119.491	88620.8	187384	-98763.5	HOP= .5
79.26	119.219	88419.4	182819	-94399.1	HOP= .5
79.884	118.948	88218	178200	-89981.6	HOP= .6
80.496	118.682	88020.6	173530	-85509.4	HOP= .6
81.096	118.421	87826.9	168812	-80984.8	HOP= .7
81.696	118.16	87633.3	164047	-76413.9	HOP= .7
82.284	117.904	87443.5	159239	-71795.3	HOP= .8
82.86	117.654	87257.6	154389	-67131.5	HOP= .9
83.436	117.403	87071.7	149498	-62426.1	HOP= .9
84	117.158	86889.7	144573	-57683	HOP= 1.
84.552	116.918	86711.5	139611	-52899.5	HOP= 1.
85.104	116.678	86533.4	134621	-48087.4	HOP= 1.
85.644	116.443	86359	129599	-43240.1	HOP= 1.
86.172	116.214	86188.6	124552	-38362.9	HOP= 1.
86.7	115.984	86018.1	119481	-33462.5	HOP= 1.
87.216	115.76	85851.6	114389	-28537.6	HOP= 1.
87.732	115.535	85685	109280	-23595	HOP= 1.
88.224	115.321	85526.1	104156	-18629.6	HOP= 1.
88.728	115.102	85363.4	99019.2	-13655.8	HOP= 1.
89.208	114.893	85208.4	93873.4	-8665.05	HOP= 1.
89.688	114.685	85053.4	88718.6	-3665.16	HOP= 1.
90.156	114.481	84902.3	83562.7	1339.6	HOP= 1.
90.612	114.283	84755	78403.6	6351.47	HOP= 1.
91.068	114.085	84607.8	73246.7	11361.1	HOP= 1.
91.512	113.891	84464.4	68097.6	16366.8	HOP= 1.
91.956	113.698	84321	62954	21366.9	HOP= 1.
92.376	113.516	84185.3	57821.6	26363.7	HOP= 2.
92.808	113.328	84045.7	52703.2	31342.5	HOP= 2.
93.216	113.151	83913.9	47602	36312	HOP= 2.
93.624	112.973	83782.1	42518.2	41264	HOP= 2.
94.02	112.801	83654.2	37460	46194.2	HOP= 2.
94.404	112.634	83530.1	32428	51102.2	HOP= 2.
94.788	112.467	83406.1	27422.3	55983.8	HOP= 2.
95.16	112.305	83285.9	22448.7	60837.2	HOP= 2.
95.532	112.143	83165.6	17512.7	65653	HOP= 2.
95.892	111.987	83049.3	12612	70437.3	HOP= 2.
96.24	111.836	82936.8	7752.38	75184.5	HOP= 2.
96.576	111.689	82828.2	2936.56	79891.7	HOP= 2.
96.912	111.543	82719.6	-1832.35	84552	HOP= 2.
97.236	111.402	82614.9	-6551.58	89166.5	HOP= 2.
97.56	111.262	82510.2	-11218.2	93728.3	HOP= 2.
97.86	111.131	82413.2	-15831.8	98245	HOP= 2.
98.172	110.995	82312.3	-20384.5	102697	HOP= 2.
98.46	110.87	82219.2	-24878.6	107098	HOP= 2.
98.748	110.745	82126.1	-29306.1	111432	HOP= 3.
99.024	110.625	82036.8	-33669.4	115706	HOP= 3.
99.288	110.51	81951.4	-37963.3	119915	HOP= 3.
99.552	110.395	81866.1	-42185	124051	HOP= 3.
99.804	110.286	81784.6	-46331.9	128116	HOP= 3.
100.056	110.176	81703.1	-50401.2	132104	HOP= 3.
100.296	110.072	81625.4	-54390.6	136016	HOP= 3.
100.524	109.973	81551.7	-58297.4	139849	HOP= 3.
100.74	109.879	81481.8	-62121.7	143603	HOP= 3.
100.956	109.785	81411.9	-65855.9	147268	HOP= 3.
101.16	109.696	81345.9	-69502.8	150849	HOP= 3.
101.364	109.607	81279.9	-73054.8	154335	HOP= 3.
101.544	109.529	81221.6	-76515	157737	HOP= 3.
101.736	109.446	81159.5	-79878.4	161038	HOP= 3.
101.904	109.373	81105.1	-83142.9	164248	HOP= 3.
102.072	109.299	81050.7	-86306.3	167357	HOP= 3.
102.228	109.232	81000.2	-89366.7	170367	HOP= 3.

102.372	109.169	80953.6	-92322	173276	HOP= 3.
102.516	109.106	80907	-95172.9	176080	HOP= 3.
102.648	109.049	80864.2	-97912.2	178776	HOP= 3.
102.78	108.992	80821.5	-100544	181365	HOP= 3.
102.9	108.939	80782.6	-103060	183843	HOP= 3.
103.008	108.892	80747.6	-105465	186213	HOP= 3.
103.104	108.851	80716.5	-107754	188471	HOP= 3.
103.2	108.809	80685.4	-109926	190612	HOP= 3.
103.284	108.772	80658.2	-111980	192638	HOP= 3.
103.356	108.741	80634.9	-113914	194549	HOP= 4.
103.428	108.71	80611.5	-115726	196338	HOP= 4.
103.488	108.684	80592	-117416	198008	HOP= 4.
103.548	108.658	80572.6	-118986	199558	HOP= 4.
103.596	108.637	80557	-120428	200985	HOP= 4.
103.632	108.621	80545.3	-121747	202292	HOP= 4.
103.656	108.611	80537.5	-122937	203474	HOP= 4.
103.68	108.6	80529.7	-124002	204532	HOP= 4.
103.692	108.595	80525.7	-124940	205466	HOP= 4.
103.692	108.595	80525.7	-340730	421256	HOP= 4.
103.692	108.595	80525.6	-341343	421868	HOP= 4.
103.692	108.595	80525.6	-341691	422216	HOP= 4.

INITIAL DEFLECTION (IN) OF TRAILS = .965015

DEFLECTION (IN) OF GUN BARREL AFTER 15 MSEC = .476448E-01
HOP HEIGHT VALUES, IF ANY, ARE IN INCHES
VENUS> LO
M20E96 logged out at 8-APR-1987 13:10:14.97

PART 4 : 7500 LB. GTHD FIRING STABILITY ANALYSIS

S. Decko - 3/10/86

ANALYSIS NOT DONE UNDER CONTRACT

7500 pound LTHD

Tow weight: 7500 lbs
Fire weight: 6900 lbs
Recoil comp. wt: 3030 lbs

Breech and auto primer wt reduced by 92.5 lbs, from 820 to 727.5 lbs.
Cannon wt reduced by 1488.5 lbs, from 2506 to 1017.5 lbs.
Previous recoil comp. wt was 4611 lbs.

Worst-case zone 8 is over max allowable recoil force by 25% over stroke length.

Worst-case zone 7 is under max allowable recoil force by 29% over stroke length.

With a zone 7 and M483 projectile, the range is roughly 14,540 meters, or 59.9% of the range (24,250 meters) provided by a 9000 lb LTHD.

F	Dist.
---	.02
50,911	.546
47,946	1.03
43,217	2
37,789	3
25,916	5
16,784	6

Stroke = 6.70 ft

F_{max} exceeded by 5 %

Hor 75 OUT. CLS

INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) = 3030
WEIGHT OF NON-RECOILING COMPONENTS (LB) = 3870
SYSTEM WEIGHT (LB) = 6900
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) = 0
PLAY IN END OF TRAILS (IN) = 0

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) = 173.139
CGY (IN) = 27.4492
CGX (IN) = 43.4391
DEFLECTION OF TRAILS (IN) = 0
MASS MOMENT OF INERTIA (FT-LB-SEC2) = 57754.4

SWEEP ANGLE LEFT (DEGREES) = 0
ELEVATION ANGLE (DEGREES) = 0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) = 0
UPWARD SLOPE OF HILL - SIDE (DEGREES) = 0

STROKE, FEET	CG-Z, INCHES	MAX FORCE LBS, W/O BACKW HOP	STA MOM FT-LBS	CG X, INCHES	MAX FORCE LBS, W/O SIDE HOP
0	173.139	49777.3	99554.7	43.4391	999999
.25	171.821	49398.6	98797.2	43.4391	999999
.5	170.504	49019.8	98039.7	43.4391	999999
.75	169.186	48641.1	97282.2	43.4391	999999
1	167.869	48262.3	96524.7	43.4391	999999
1.25	166.552	47883.6	95767.2	43.4391	999999
1.5	165.234	47504.8	95009.7	43.4391	999999
1.75	163.917	47126.1	94252.2	43.4391	999999
2	162.599	46747.3	93494.7	43.4391	999999
2.25	161.282	46368.6	92737.2	43.4391	999999
2.5	159.965	45989.8	91979.7	43.4391	999999
2.75	158.647	45611.1	91222.2	43.4391	999999
3	157.33	45232.3	90464.7	43.4391	999999
3.25	156.013	44853.6	89707.2	43.4391	999999
3.5	154.695	44474.8	88949.7	43.4391	999999
3.75	153.378	44096.1	88192.2	43.4391	999999
4	152.06	43717.3	87434.7	43.4391	

999999				
4.25	150.743	43338.5	86677.2	43.4391
999999				
4.5	149.426	42959.5	85919.7	43.4391
999999				
4.75	148.108	42581.1	85162.2	43.4391
999999				
5	146.791	42202.3	84404.7	43.4391
999999				
5.25	145.473	41823.6	83647.2	43.4391
999999				
5.5	144.156	41444.8	82889.7	43.4391
999999				
5.75	142.839	41066.1	82132.2	43.4391
999999				
6	141.521	40687.3	81374.7	43.4391
999999				
6.25	140.204	40308.6	80617.2	43.4391
999999				
6.5	138.886	39929.8	79859.7	43.4391
999999				
6.75	137.569	39551.1	79102.2	43.4391
999999				
7	136.252	39172.3	78344.7	43.4391
999999				
7.25	134.934	38793.6	77587.2	43.4391
999999				
7.5	133.617	38414.8	76829.7	43.4391
999999				
7.75	132.299	38036.1	76072.2	43.4391
999999				
8	130.982	37657.3	75314.7	43.4391
999999				
8.25	129.665	37278.6	74557.2	43.4391
999999				

HOP HT VALUES, IF ANY, ARE IN INCHES

WT,7000.US

58

INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) = 3398.31
WEIGHT OF NON-RECOILING COMPONENTS (LB) = 3000.35
SYSTEM WEIGHT (LB) = 6398.66
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) = 0
PLAY IN END OF TRAILS (IN) = 0

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) = 181.377
CGY (IN) = 26.6073
CGX (IN) = 43.5311
DEFLECTION OF TRAILS (IN) = 0
MASS MOMENT OF INERTIA (FT-LB-SEC2) = 57249.6

SWEEP ANGLE LEFT (DEGREES) = 0
ELEVATION ANGLE (DEGREES) = 0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) = 0
UPWARD SLOPE OF HILL - SIDE (DEGREES) = 0

STROKE, FEET	CG-Z, INCHES	MAX FORCE LBS, W/O BACKW HOP	STA M.M FT-LBS	CG X, INCHES	MAX FORCE SIDE HOP
0	181.377	48367	96714	43.5311	999999
.25	179.784	47932.2	95864.4	43.5311	999999
.5	178.192	47507.4	95014.8	43.5311	999999
.75	176.598	47082.6	94165.2	43.5311	999999
1	175.004	46657.8	93315.7	43.5311	999999
1.25	173.411	46233.1	92465.1	43.5311	999999
1.5	171.819	45808.3	91615.5	43.5311	999999
1.75	170.224	45383.5	90767	43.5311	999999
2	168.631	44958.7	89917.4	43.5311	999999
2.25	167.038	44533.9	89067.8	43.5311	999999
2.5	165.444	44109.1	88218.2	43.5311	999999
2.75	163.851	43684.3	87368.7	43.5311	999999
3	162.258	43259.5	86519.1	43.5311	999999
3.25	160.665	42834.8	85669.5	43.5311	999999
3.5	159.071	42410	84819.9	43.5311	999999
3.75	157.478	41985.2	83970.4	43.5311	999999
4	155.885	41560.4	83120.8	43.5311	

999999				
4.25	154.291	41135.5	82271.2	43.5311
999999				
4.5	152.698	40710.8	81421.6	43.5311
999999				
4.75	151.105	40286	80572	43.5311
999999				
5	149.512	39861.2	79722.5	43.5311
999999				
5.25	147.918	39436.4	78872.9	43.5311
999999				
5.5	146.325	39011.7	78023.3	43.5311
999999				
5.75	144.732	38586.9	77173.7	43.5311
999999				
6	143.138	38162.1	76324.2	43.5311
999999				
6.25	141.545	37737.3	75474.6	43.5311
999999				
6.5	139.952	37312.5	74625	43.5311
999999				
6.75	138.358	36887.7	73775.4	43.5311
999999				
7	136.765	36462.9	72925.9	43.5311
999999				
7.25	135.172	36038.1	72076.3	43.5311
999999				
7.5	133.579	35613.3	71226.7	43.5311
999999				
7.75	131.985	35188.5	70377.1	43.5311
999999				
8	130.392	34763.8	69527.5	43.5311
999999				
8.25	128.799	34339	68678	43.5311
999999				

HDP HT VALUES, IF ANY, ARE IN INCHES

WT. 8000.45

60

INITIAL CONDITIONS:
WEIGHT OF RECOILING COMPONENTS (LB) = 3928.57
WEIGHT OF NON-RECOILING COMPONENTS (LB) = 3468.49
SYSTEM WEIGHT (LB) = 7397.06
INDIV. TRAIL'S SPRING CONSTANT (LB/IN) = 0
PLAY IN END OF TRAILS (IN) = 0

AT MAXIMUM EXTENSION OF BARREL:
CGZ (IN) = 181.377
CGY (IN) = 26.6073
CGX (IN) = 43.5311
DEFLECTION OF TRAILS (IN) = 0
MASS MOMENT OF INERTIA (FT-LB-SEC2) = 55239.4

SWEEP ANGLE LEFT (DEGREES) = 0
ELEVATION ANGLE (DEGREES) = 0
UPWARD SLOPE OF HILL - FORWARD (DEGREES) = 0
UPWARD SLOPE OF HILL - SIDE (DEGREES) = 0

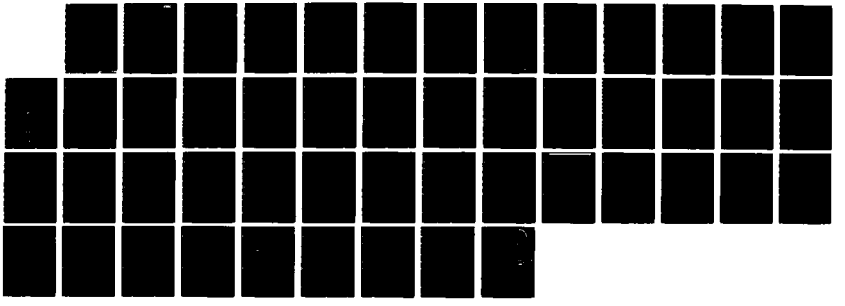
STROKE, FEET	CG-Z, INCHES	MAX FORCE LBS, W/O BACKW HOP	STA MOM FT-LBS	CG X, INCHES	MAX FORCE LBS, W/O SIDE HOP
0	181.377	55902.5	111805	43.5311	999999
.25	179.734	55411.5	110823	43.5311	999999
.5	178.191	54920.4	109841	43.5311	999999
.75	176.598	54429.3	108859	43.5311	999999
1	176.004	53938.2	107876	43.5311	999999
1.25	173.411	53447.2	106894	43.5311	999999
1.5	171.818	52956.1	105912	43.5311	999999
1.75	170.224	52465	104930	43.5311	999999
2	168.631	51974	103948	43.5311	999999
2.25	167.038	51482.9	102966	43.5311	999999
2.5	165.445	50991.8	101984	43.5311	999999
2.75	163.851	50500.8	101002	43.5311	999999
3	162.258	50009.7	100019	43.5311	999999
3.25	160.665	49518.6	99037.2	43.5311	999999
3.5	159.071	49027.5	98055.1	43.5311	999999
3.75	157.478	48536.5	97072.9	43.5311	999999
4	155.885	48045.4	96090.8	43.5311	

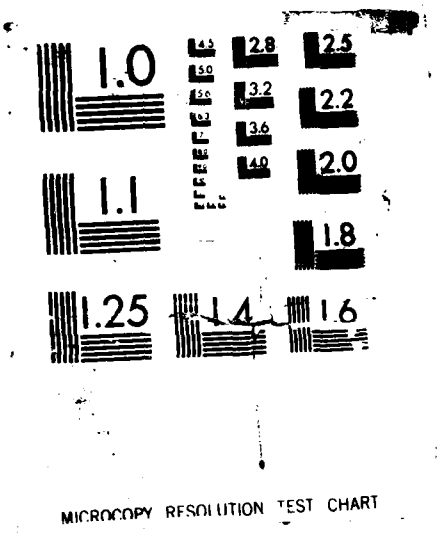
999999				
4.25	154.291	47554.3	95108.6	43.5311
999999				
4.5	152.698	47063.2	94126.5	43.5311
999999				
4.75	151.105	46572.2	93144.3	43.5311
999999				
5	149.512	46081.1	92162.2	43.5311
999999				
5.25	147.918	45590	91180.1	43.5311
999999				
5.5	146.325	45099	90197.9	43.5311
999999				
5.75	144.732	44607.9	89215.8	43.5311
999999				
6	143.138	44116.8	88233.6	43.5311
999999				
6.25	141.545	43625.7	87251.5	43.5311
999999				
6.5	139.952	43134.7	86269.3	43.5311
999999				
6.75	138.358	42643.6	85287.2	43.5311
999999				
7	136.765	42152.5	84305.1	43.5311
999999				
7.25	135.172	41661.5	83322.9	43.5311
999999				
7.5	133.579	41170.4	82340.8	43.5311
999999				
7.75	131.985	40679.3	81358.6	43.5311
999999				
8	130.392	40188.2	80376.5	43.5311
999999				
8.25	128.799	39697.2	79394.3	43.5311
999999				

HOP HT VALUES, IF ANY, ARE IN INCHES

AD-A183 985 LIGHTWEIGHT TOWED HOWITZER DEMONSTRATOR PHASE 1 AND PARTIAL PHASE 2 VOLUM (U) FMC COR MINNEAPOLIS MINN NORTHERN ORDNANCE DIV R RATHE ET AL APR 87 3/3

UNCLASSIFIED FMC-E-3041-VOL-C-PT-1 DAAA21-86-C-0047 F/G 19/6 NL



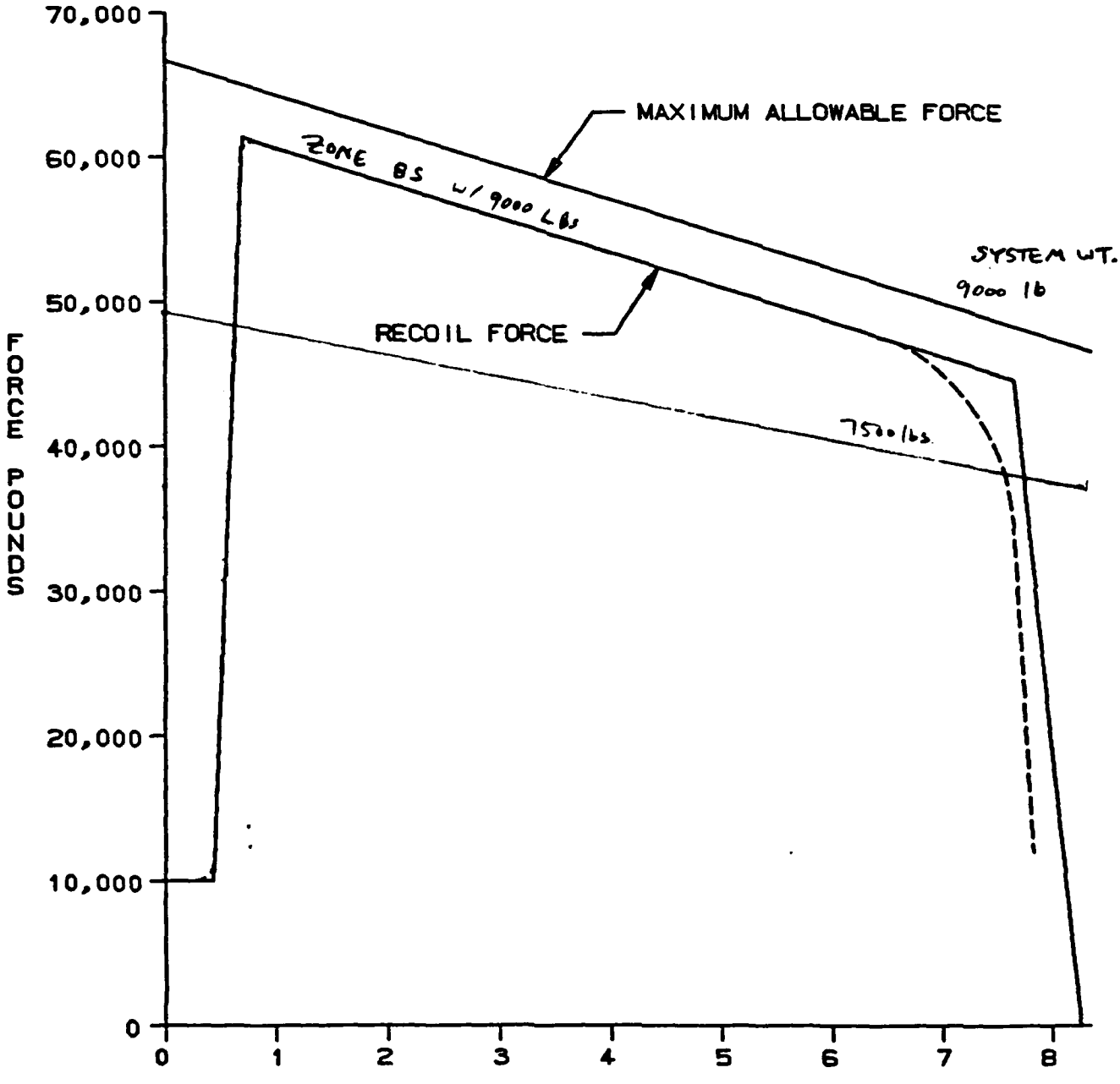


MICROCOPY RESOLUTION TEST CHART

FMC

(62)

RECOIL FORCE VS STROKE
WORST CASE



LTHD
4 MARCH 1986
SD
COMPETITION SENSITIVE

(C

BL = 198.6"

Frec = 10,000 lbs.

RECOIL DIST, FT

Time, msec.	20.2" B.L. MASS = 866 lbs 8SAKMASLR	8M4832R	7M4832R	202" B.L. MASS = 303.0 lbs. 8SAKMASLR	8M4832R	7M4832R
11	.3297	.156	.098	.501	.238	.149
12	.397	.201	.130	.604	.306	.198
13	.466	.249	.164	.709	.379	.250
14	.536	.300	.200	.815	.457	.305
15	.606	.352	.238	.921	.536	.363
16	.676	.406	.278	1.028	.619	.422
17	.746	.461	.318	1.136	.701	.489
18	.517	.516	.359	1.244	.755	.547
19	.889	.571	.401	1.353	.869	.611
20	.961	.626	.443	1.462	.953	.674
Est. at BL=202		.410	.390			
10				.4632		

5.0 → 5.3" → .441

8.5"

BL = 202"

What should safety margin be?

5" : .416
6" : .5 (16.8% Safety margin)
7" : .583
6.5" : .596 (13.9% " ")

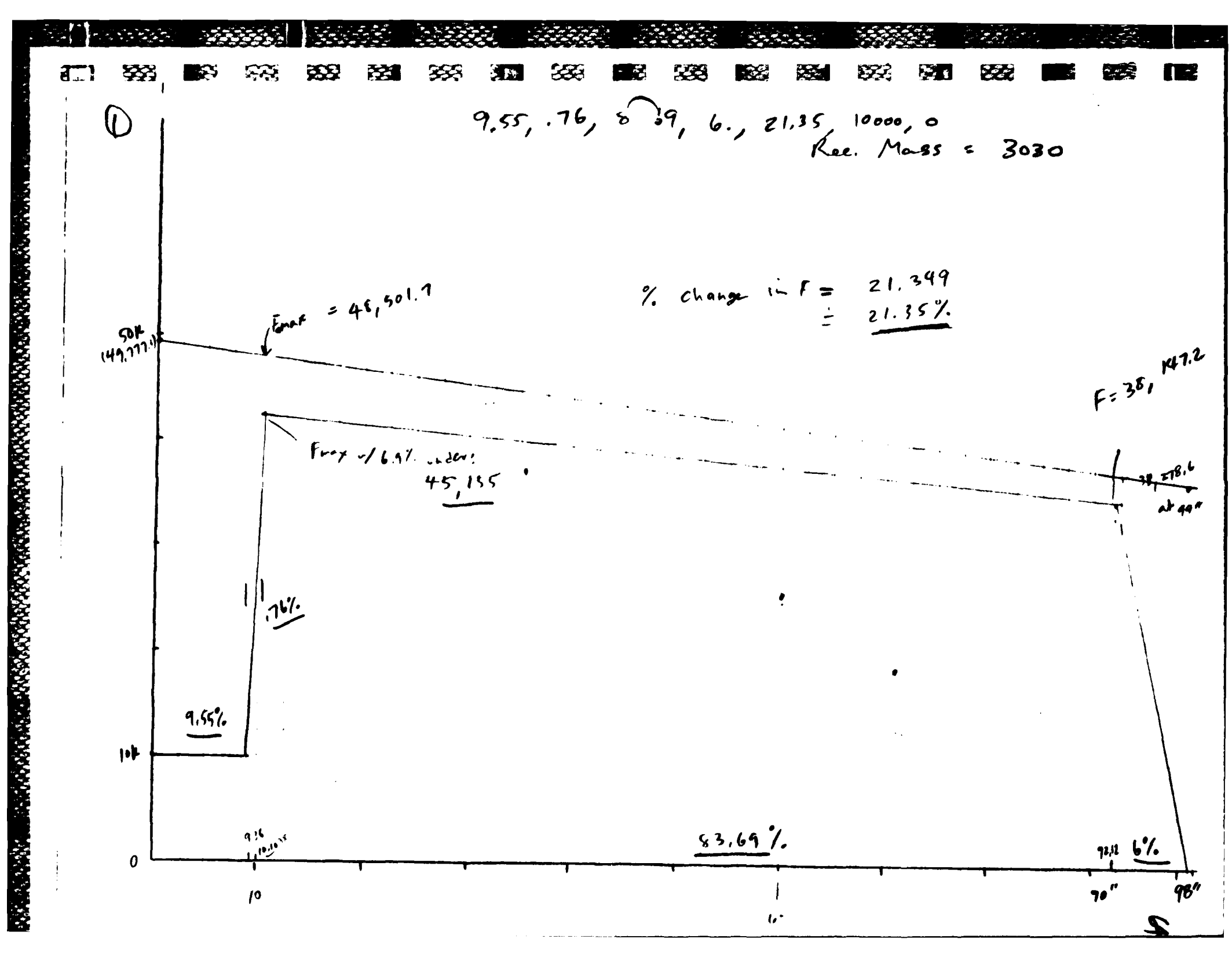
∴ 5" → 6.5"

6.5" free recoil

Zone 85 is design charge for free recoil length determination

39 1/3 CAL = 242" = 202' BL

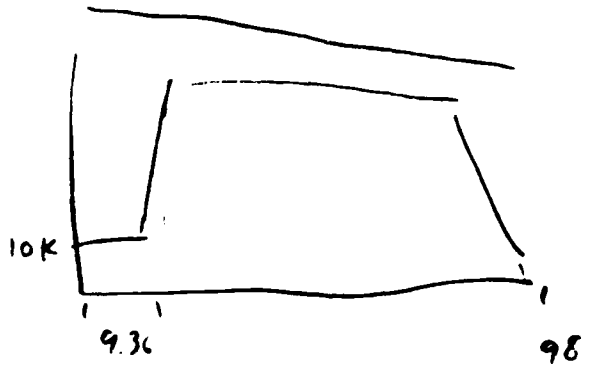
9.35" free recoil


9.55, .76, 8 39, 6., 21.35, 10000, 0
Rec. Mass = 3030
% change in F = 21.349
≈ 21.35%
Emax = 48,301.7
SOL (49,777.1)
Fmax w/ 6.9% under: 45,135
F = 38,147.2
38, 178.6 at 49"
.76%
9.55%
10k
0
9.55 10.10"
83.69%
92.12
6%
10
70"
98"

(2) 198.6 ÷ 199 + 2 = 200# Band.

Lighter Wt. : 3030 lbs Rec. Mass

Must have : 9.36" free recoil



See (1)

Results cannot Fire Zone 8 w/M483

CAN Fire Zone 7 w/ M483

6.9% under: stroke = 6.26'

Recoil must be looked at to change trapezoids!

Fmax 40k	Str.
45, 155	6.65
34k	6.26
→ 32k	7.89

over 15 ft/sec.

% under max F = 29.69 ÷ 30%

(3)

8M483R

Flux	% under/over	58Ti, Ø
45,155	− 6.9	8,16 +
48,501	0	8,16 + (V = 40.78)
		" (V = 18)
58,201	+ 20	
		7,59
63,651	+ 30	

over by ≐ 25 %

PART NUMBER: 12585727, Lanyard Actuator

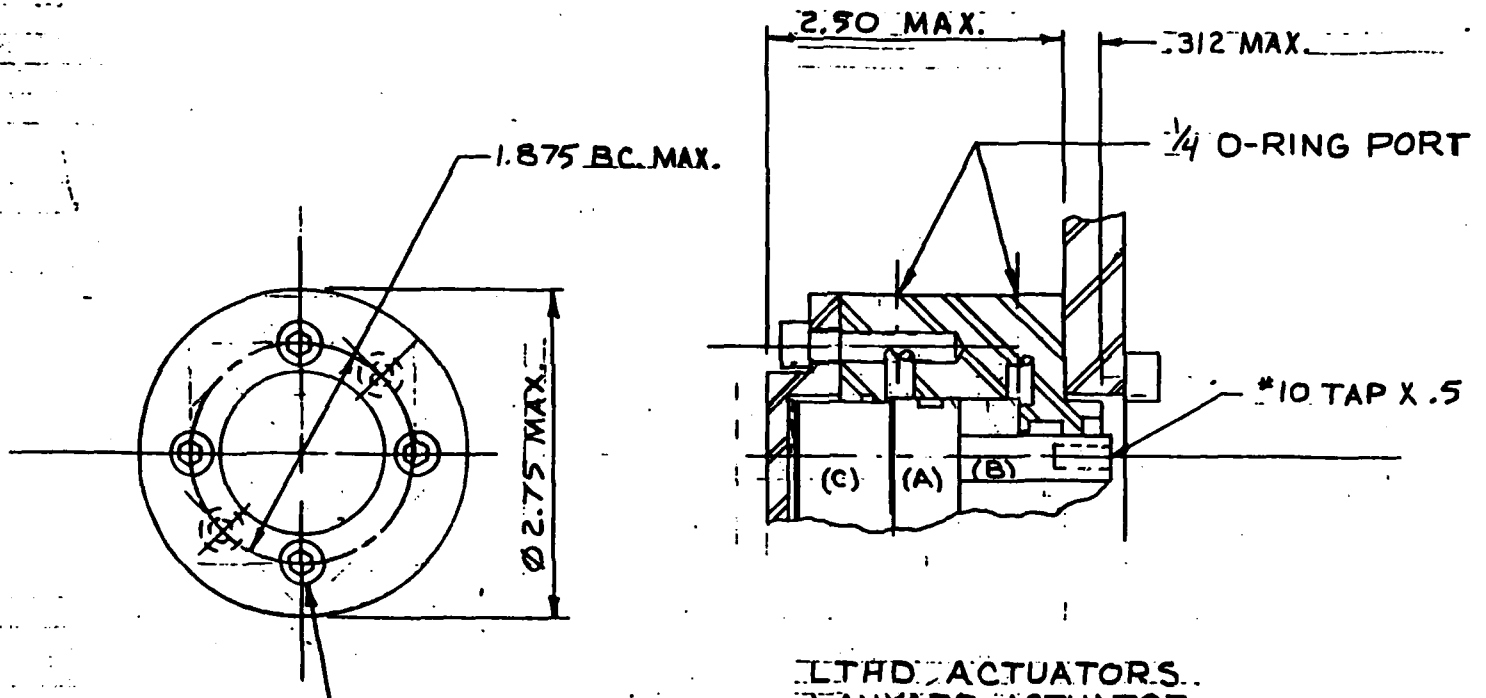
DESCRIPTION: LANYARD ACTUATOR

STATUS:

Size and mounting specifications were provided to York for final design. These requirements were developed to be compatible with the FMC primer autoloader.

All hoses, fittings and connectors have been finalized and are specified on FMC TDP gang-sheets. Layouts of the lanyard actuator and hoses can be found in the TDP, Cannon Assembly.

AUTHOR: Joe Turek



LTHD ACTUATORS.
LANYARD ACTUATOR
(A.) PISTON DIA. .9687
(B.) ROD .375
(C.) ROD .875
WORKING PRESSURE 3000 PSI
STROKE .5
RETURN PRESSURE 100 - 300 PSI
SHOCK FACTOR 20 g's
EXTEND FORCE 345 Lbs.
EXTEND OIL FLOW .14 GPM.
ACTUATOR WEIGHT 1 Lbs.

LTHD ACTUATORS

LANYARD ACTUATOR

PISTON DIA		in.
ROD DIA		in.
WORKING PRESSURE	3000	psi
PROOF PRESSURE	4500	psi
EXTEND FORCE	200	lbs.
EXTEND OIL FLOW		gpm
RETRACT FORCE	50	lbs.
RETRACT OIL FLOW		gpm
EXTENDED LENGTH	4.125	in.
RETRACTED LENGTH	3.5	in.
STROKE	0.500	in.
EXTEND CUSHION LENGTH		in.
RETRACT CUSHION LENGTH		in.
ACTUATOR ENDS:		
CYLINDER END	BOLTED TO AUTO-PRIMER	
ROD END	EYE	
ACTUATOR WEIGHT	1	lbs.
SHOCK FACTOR	20	g's

COMMENTS:

LANYARD P. 1 OF 1

.25 SEC $\frac{60}{.25} = 240 \times .5 = 120$ "PER MIN (STROKE)

A 1" = .785 $.1358 \times 120 = \frac{16.294}{231} = .0705$ GPM

A = 7/8 = .6013 $\times 2$

A: 31/32 .737 $.737 - .1104 = .6266$ .1411

A = 3/8 = .1104

P		A		F
3000 PSI	X	.1358	=	408
100 PSI	X	.6266	=	62.7
300 PSI	X	.6266	=	188

$408 - 62.7 = 345$ #

345 ON LANYARD NEEDED 200

OK PER TIM 1/27/87

A X LGH SQ

.1358 X .187 = .0254 $S = \frac{345}{.0254} = 13,585$

ON O-RING LAND

$Y = 50,000 (.577) = 28,850$

A = 1" = .994 $.3927 \times .187 = .0734$ (A)

A = 7/8 = .6013

DIFF .3927

X 3000 PSI

F = 1,178 #

$\frac{P}{A} \quad \frac{1178}{.0734} = S = 16,049$

LANYARD

(A) PRES. HOSE LG. = 16.00

R= 4.238 = C 26.628 ÷2= 13.314 +.312 +.312 +. 1.58 +1.5

= 17.098 − (.*55 x 2) = 15.998

*.55 =X= 

(B) RETURN HOSE LG = 16.375

R. 4.062 +. 30 = 4.362 = C = 27.4073 ÷2= 13.7

13.703 + (.312x2) + (1.58 x2) = 17.487 - (.*55x2) = 16.387

16.375

BOTH HOSES TO BE 16.375 LG.

3/2/87

PRIMER TO LANYARD HOSES

[redacted] OVER ALL LG 17.487

C/160 -1

PART NUMBER: 12585728, Load Position Actuator

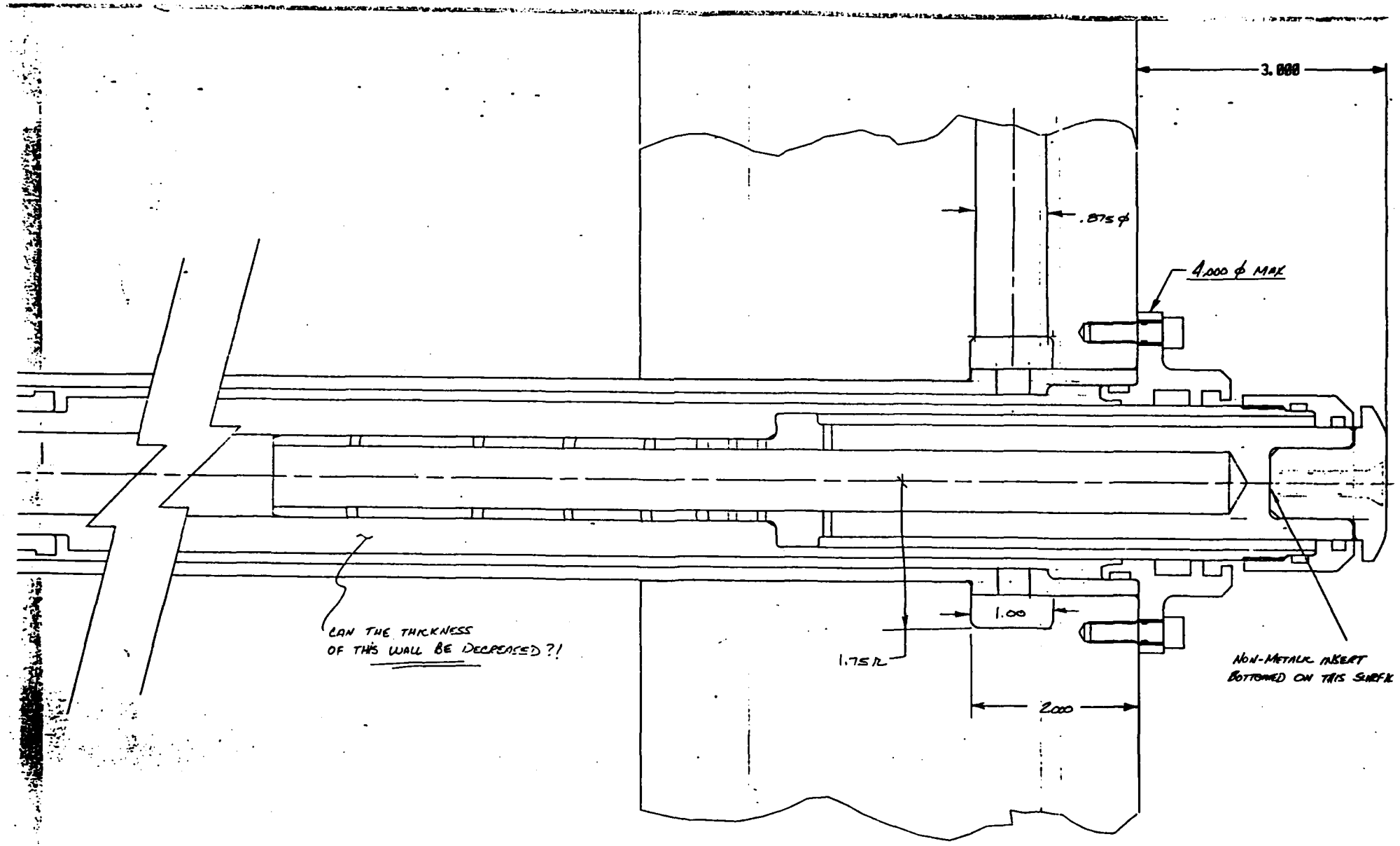
DESCRIPTION: LOAD POSITION ACTUATOR

This actuator controls the cannon position. The actuator is used to drive the cannon to the load position from battery, hold the cannon to the load position, or return the cannon to the battery position from the load position. It also serves as a counter-recoil buffer when returning to either load or battery positions.

STATUS:

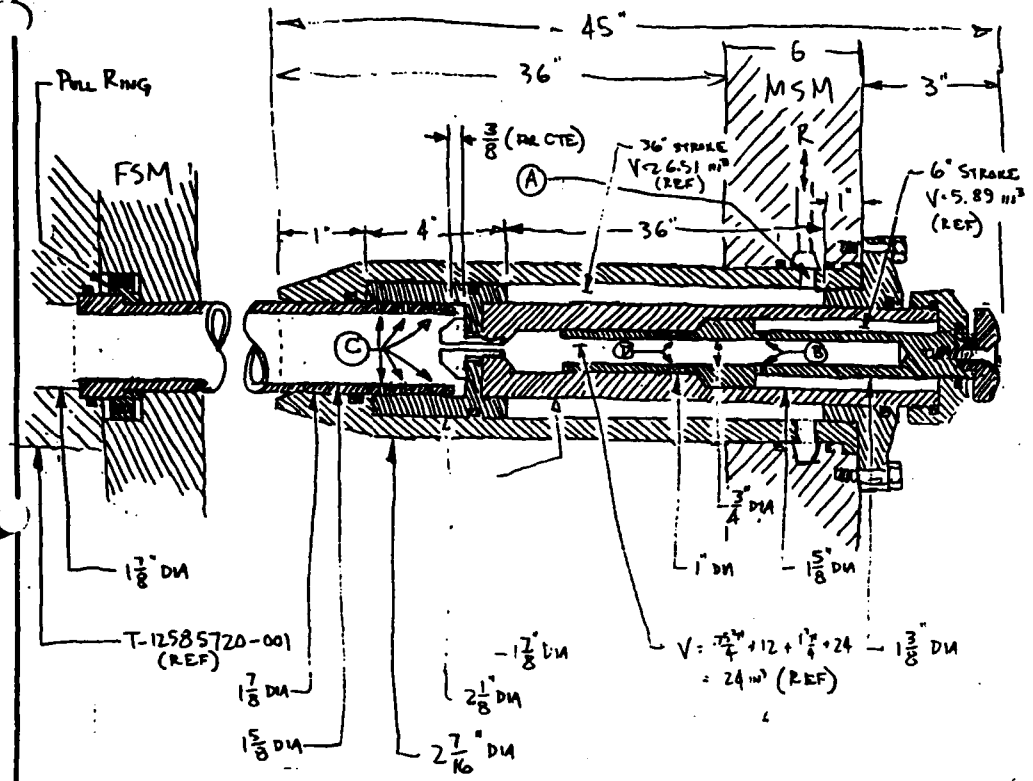
Size and mounting specifications were provided to York for finalized design.

AUTHOR: Jeff Ireland


3.000
.875 ϕ
4.000 ϕ MAX
CAN THE THICKNESS
OF THIS WALL BE DECREASED?!
1.00
1.75 R
2.000
NON-METALIC INSERT
BOTTOMED ON THIS SURFACE

DRAWING SIZE B

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL



(A) 1/4" Extend Cushion - Main Rod
(B) 1/8" Extend Cushion - Secondary Rod
(C) 2" Retract Cushion - Main Rod
(D) 6" Retract Cushion - Secondary Rod

REF. DWG.	DESCRIPTION
T-1258 5717	YORK SPREAD SHEET
1258 5710-460	HYDRAULIC FUNCTIONAL

PART NO.

NEXT ASSY	USED ON
APPLICATION	

MECHANICAL PROPERTIES	
YP	
TS	
EL2	
RA	
BH	
RH	

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES ON DECIMALS ±

FRACTIONS ± ANGLES ±

THIRD ANGLE PROJECTION

ORIGINAL DATE OF DRAWING

DRAFTSMAN	CHECKER
ENGR	ENGR
ENGR	ENGR

U.S. ARMY
ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
DOVER, NEW JERSEY 07801-5001

LOAD POSITION ACTUATOR

SIZE	FSCM NO.	
B	19200	T-1258 5728 /B
SCALE	UNIT WT.	SHEET

SMCAR FORM 66, 1 JUN 86(TEMP) REPLACES ARRADCOM FORM 66, AUG 77.

DESCRIPTION: LOADING SYSTEM

The LTHD loading system consists of a load tray, projectile carrier, inertial rammer actuator and ram velocity control valve, and ram control. For a description of the operational procedures for loading, the reader is referred to the TDP, Dwgs. 12585710-825, pp. 3 (Loading Controls),12 (Max Rate of Fire Timeline), 13-14 (Max Rate of Fire Procedures) and 15-17 (Sustained Rate of Fire Procedures).

STATUS:

Load Tray. Layouts of the load tray design have been completed and a majority of the components can be found in the TDP as preliminary drawings. The current load tray assembly uses graphite epoxy as the primary material; however, a study was begun to re-evaluate the use of aluminum. The load tray configuration was designed to withstand all LTHD load conditions with the exception of being able to withstand firing loads with a projectile in the tray at the time of firing.

Projectile Carrier. The function of the separable projectile carrier is to provides a simple means for two cannoneers to carry projectiles to the load tray and place the projectile in the tray without getting their fingers or hands pinched or injured. This part has not yet reached the layout stage.

Rammer Actuator and Ram Velocity Control Valve. A ramming sytem consisting of a hydraulic actuator (TDP, Dwg. 12585729) and ram velocity control valve (TDP, Dwg. 12585902) has been developed to ram the load tray and projectile and provide the required ram velocity for proper projectile seating at all loading QE's. The motion provided includes an initial slow velocity to round the travel path bend that exists between 0 and 600 mils, and then fast ram velocity which seats the projectile. Actuator sizing and preliminary orifice sizing have been determined; fine-tuning of the system to achieve required ram velocities would take place during testing.

Ram Control. A Marotta-developed ram control valve (TDP, Dwg. 12585900-002) initiates the ram cycle and the cannoneer has a choice of ramming either fast or slow. The slow ram option is only used if a projectile such as a Copperhead is to be manually rammed or if the load tray is to be positioned behind the breech to remove an unfired or stuck projectile. All requirements for this component have been completed.

AUTHORS: Kent Williams, Ron Larson, Bart Anderson, Jeff Ireland

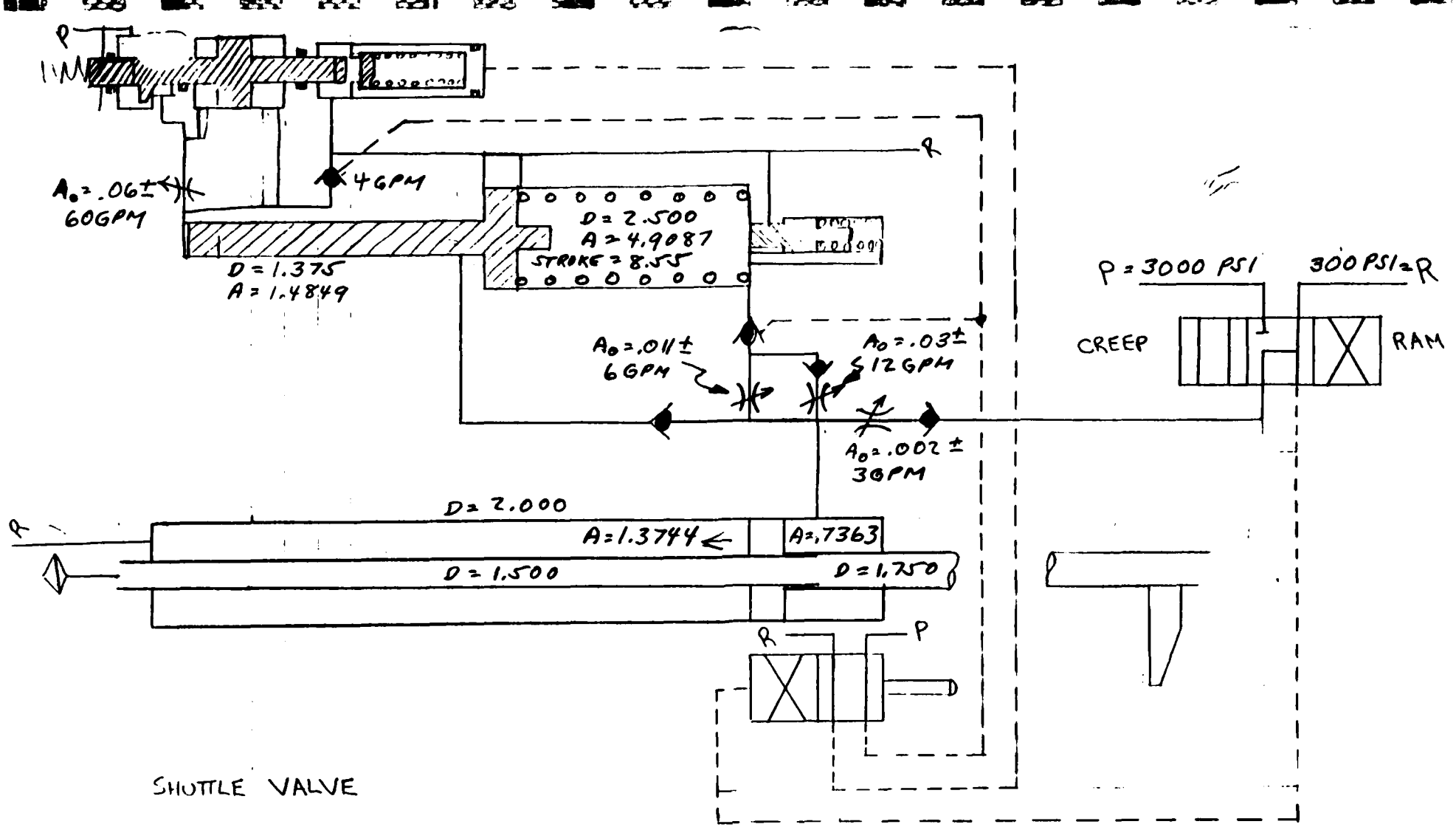
LTHD Rammer Circuit

The attached circuit diagram and calculator printout show the critical dimensions and performance predictions for the rammer system.

Analysis of the operating parameters indicates the need for four variable orifices for independent control of slow speed control of the projectile and tray through the transition tracks, high speed control of maximum ramming velocity, control of creep speed when using copperhead projectile, and control of tray return speed to the load position.

The two calculator runs at the extreme ends of operating temperature range indicate a minimal sensitivity to temperature, and optimum performance should be obtainable with fine tuning adjustments on the demonstrator model.

Additional analysis of the de-equalizer shows that the ratio of areas of 3.3:1 is near optimum. However, piston diameters can be changed if desirable as long as this area ratio is maintained.



WEIGHT
OIL CONS.
TIME CYCLE
FLEXIBILITY

RAMMER DATA

03/02/87 11:36:10 AM

M1=0.0130
M2=0.4275
PA=3,000.0000
PR=300.0000
D1=1.3750
D2=2.5000
D3=2.0000
D4=1.7500
D5=1.5000
D6=1.8990
D7=1.8500
A01=0.0600
A02=0.0300
A03=0.0110
A04=0.7854
A05=0.7854
L1=18.2500
L2=2.0000
L3=4.0000
L4=87.0000
NU=0.8000 → (-25°F.)
RHO=0.0308
G=386.0000
MU=0.0001
A1=1.4849
A2=3.4238
A3=4.9087
A4=0.7363
A5=1.3744
C1=0.0256
C2=0.0920
C3=0.0699
C4=0.0122
C5=1.7116
WT=165.0000
ANG=33.7500
FRC=0.1000

R60= 711.9815
R61= 0.5795
R62= 10.2705
R63= 0.0047
R64= 711.9815
R65= 0.5795
R66= 15.6912
R67= -2.7056
R68= 711.9815
R69= 0.5795
R70= 4.0497
R71= 0.0047
R72= 3,956.4063
R73= 0.0203
R74= 4.8531
R75= 0.0047
R76= -1,319.2192
R77= 0.1996
R78= 12.3193
R79= 0.0120

TIME	X	VEL	ACC
0.00	0.0	0.0	712.0
0.01	3.6-02	7.1	609.5
0.02	0.1	13.2	475.1
0.03	0.3	18.0	340.4
0.04	0.5	21.4	227.8
0.05	0.7	23.6	145.0
0.06	1.0	25.1	89.1
0.07	1.2	26.0	53.5
0.08	1.5	26.5	31.7
0.09	1.7	26.8	18.6
0.10	2.0	27.0	11.8
0.11	2.3	27.1	26.8
0.12	2.6	27.4	36.0
0.13	2.8	27.8	42.1
0.14	3.1	28.2	46.4
0.15	3.4	28.7	49.8
0.16	3.7	29.2	52.7
0.17	4.0	29.7	55.3
0.18	4.3	30.2	35.0
0.20	4.9	30.9	6.7
0.22	5.5	31.1	1.1
0.24	6.1	31.1	0.1
0.26	6.8	31.1	-0.1
0.28	7.4	31.1	-0.1
0.30	8.0	31.1	-0.1
0.32	8.6	31.1	-0.1
0.34	9.2	31.1	-0.1
0.36	9.9	31.1	-0.1
0.38	10.5	31.1	-0.1
0.40	11.1	31.1	-0.1
0.42	11.7	31.1	-0.1
0.44	12.3	31.1	-0.1
0.46	13.0	31.1	-0.1
0.48	13.6	31.1	-0.1
0.50	14.2	31.1	-0.1
1.66	50.2	30.9	-0.1
1.68	50.8	30.9	-0.1
1.70	51.4	30.9	-0.1
1.72	52.0	30.9	-0.1
1.74	52.7	30.9	-0.1
1.76	53.3	30.9	-0.1
1.78	53.9	30.9	-0.1
1.80	54.5	30.9	-0.1
1.82	55.1	30.9	-0.1
1.84	55.7	30.9	-0.1
1.86	56.4	30.9	-0.1
1.88	57.0	30.9	-0.1
1.90	57.6	30.9	3,778.6
1.91	58.1	68.7	3,508.3
1.92	59.0	103.8	3,205.2
1.93	60.2	135.8	2,884.0
1.94	61.7	164.7	2,558.8
1.95	63.4	190.3	2,241.2
1.96	65.4	212.7	1,940.4
1.97	67.7	232.1	1,662.6
1.98	70.1	248.7	1,411.5
1.99	72.6	262.8	1,188.6
2.00	75.3	274.7	993.7
2.01	78.1	284.6	825.3
2.02	81.0	292.9	681.5
2.03	84.0	299.7	559.6
2.04	87.0	305.3	457.1

RETRACT RAM			
0.00	87.0	0.0	-1,319.2
0.02	86.7	-26.4	-827.7
0.04	86.0	-42.9	-377.8
0.06	85.1	-50.5	-136.6
0.08	84.1	-53.2	-44.2
0.10	83.0	-54.1	-14.2
0.12	81.9	-54.4	-5.0
0.14	80.8	-54.5	-2.2
0.16	79.7	-54.5	-1.4
0.18	78.6	-54.6	-1.1
0.20	77.6	-54.6	-1.1
0.22	76.5	-54.6	-1.0
0.24	75.4	-54.6	-1.0
0.26	74.3	-54.7	-1.0
0.28	73.2	-54.7	-1.0
0.30	72.1	-54.7	-1.0
0.32	71.0	-54.7	-1.0
0.34	69.9	-54.7	-1.0
0.36	68.8	-54.8	-1.0
0.38	67.7	-54.8	-1.0
0.40	66.6	-54.8	-1.0
0.42	65.5	-54.8	-1.0
0.44	64.4	-54.8	-1.0
0.46	63.3	-54.9	-1.0
0.48	62.2	-54.9	-1.0
0.50	61.1	-54.9	-1.0
0.52	60.0	-54.9	-1.0
0.54	58.9	-54.9	-1.0
0.56	57.8	-55.0	-1.0
0.58	56.7	-55.0	-1.0
0.60	55.6	-55.0	-1.0
0.62	54.5	-55.0	-1.0
1.02	32.4	-55.4	-1.1
1.04	31.3	-55.5	-1.1
1.06	30.2	-55.5	-1.1
1.08	29.1	-55.5	-1.1
1.10	28.0	-55.5	-1.1
1.12	26.9	-55.5	-1.1
1.14	25.8	-55.6	-1.1
1.16	24.7	-55.6	-1.1
1.18	23.6	-55.6	-1.1
1.20	22.4	-55.6	-1.1
1.22	21.3	-55.7	-1.1
1.24	20.2	-55.7	-1.1
1.26	19.1	-55.7	-1.1
1.28	18.0	-55.7	-1.1
1.30	16.9	-55.7	-1.1
1.32	15.8	-55.8	-1.1
1.34	14.6	-55.8	-1.1
1.36	13.5	-55.8	-1.1
1.38	12.4	-55.8	-1.1
1.40	11.3	-55.8	-1.1
1.42	10.2	-55.9	-1.1
1.44	9.1	-55.9	-1.1
1.46	7.9	-55.9	-1.1
1.48	6.8	-55.9	-1.1
1.50	5.7	-56.0	-1.1
1.52	4.6	-56.0	-1.1
1.54	3.5	-56.0	-1.1
1.56	2.3	-56.0	-1.1
1.58	1.2	-56.0	-1.1
1.60	0.1	-56.1	-1.1

END OF STROKE

RAMMER DATA

03/02/87 1:20:10 PM

M1=0.0130
M2=0.4275
PA=3,000.0000
PR=300.0000
B1=1.3750
B2=2.5000
B3=2.0000
B4=1.7500
B5=1.5000
B6=1.8800
B7=1.8500
A01=0.0600
A02=0.0300
A03=0.0110
A04=0.7854
A05=0.7854
L1=18.2500
L2=2.0000
L3=4.0000
L4=87.0000
NU=0.0090 → (+160° F.)
RHO=0.0300
G=386.0000
MU=6.3834E-7
A1=1.4849
A2=3.4238
A3=4.9087
A4=0.7363
A5=1.3744
C1=0.0003
C2=0.0009
C3=0.0007
C4=0.0091
C5=0.0171
WT=165.0000
ANG=33.7500
FRC=0.1000

R60= 711.9815
R61= 0.5795
R62= 0.1027
R63= 4.7298-05
R64= 711.9815
R65= 0.5795
R66= 0.1569
R67= -0.0271
R68= 711.9815
R69= 0.5795
R70= 0.0485
R71= 4.7298-05
R72= 3,956.4063
R73= 0.0203
R74= 0.0485
R75= 4.7330-05
R76= -1,319.2192
R77= 0.1996
R78= 0.1232
R79= 0.0001

TIME	X	VEL	ACC
0.00	0.0	0.0	712.0
0.01	3.6-02	7.1	681.9
0.02	0.1	13.9	598.0
0.03	0.3	19.9	480.0
0.04	0.5	24.7	355.3
0.05	0.8	28.3	245.9
0.06	1.1	30.7	161.5
0.07	1.4	32.3	102.3
0.08	1.7	33.4	63.2
0.09	2.1	34.0	38.6
0.10	2.4	34.4	23.6
0.11	2.8	34.6	14.4
0.12	3.1	34.8	8.9
0.13	3.5	34.9	5.7
0.14	3.8	34.9	3.7
0.15	4.2	34.9	2.4
0.17	4.9	35.0	0.4
0.19	5.6	35.0	0.1
0.21	6.3	35.0	1.4-02
0.23	7.0	35.0	1.5-03
0.25	7.7	35.0	5.7-04
0.27	8.4	35.0	-1.3-03
0.29	9.1	35.0	-1.4-03
0.31	9.8	35.0	-1.4-03
0.33	10.5	35.0	-1.4-03
0.35	11.2	35.0	-1.4-03
0.37	11.9	35.0	-1.4-03
0.39	12.6	35.0	-1.4-03
0.41	13.3	35.0	-1.4-03
0.43	14.0	35.0	-1.4-03
0.45	14.7	35.0	-1.4-03
0.47	15.4	35.0	-1.4-03
0.49	16.1	35.0	-1.4-03
1.43	49.0	35.0	-1.4-03
1.45	49.7	35.0	-1.4-03
1.47	50.4	35.0	-1.4-03
1.49	51.1	35.0	-1.4-03
1.51	51.8	35.0	-1.4-03
1.53	52.5	35.0	-1.4-03
1.55	53.2	35.0	-1.4-03
1.57	53.9	35.0	-1.4-03
1.59	54.6	35.0	-1.4-03
1.61	55.3	35.0	-1.4-03
1.63	56.0	35.0	-1.4-03
1.65	56.7	35.0	-1.4-03
1.67	57.4	35.0	3,929.7
1.68	57.9	74.3	3,840.5
1.69	58.8	112.7	3,692.8
1.70	60.2	149.6	3,494.2
1.71	61.8	184.6	3,255.4
1.72	63.8	217.1	2,988.3
1.73	66.2	247.0	2,705.2
1.74	68.8	274.1	2,417.6
1.75	71.6	298.2	2,135.5
1.76	74.7	319.6	1,866.5
1.77	78.0	338.3	1,616.3
1.78	81.5	354.4	1,388.1
1.79	85.1	368.0	1,182.7

RETRACT RAM

0.90 87.0 0.0-1,319.2
0.92 86.7-26.4-1,176.7
0.94 86.0-49.9-815.1
0.96 84.8-66.2-435.0
0.98 83.4-74.9-188.6
1.00 81.9-78.7-72.5
1.02 80.3-80.1-26.3
1.04 78.7-80.7-9.4
1.06 77.1-80.9-3.3
1.08 75.4-80.9-1.2
1.10 73.8-81.0-0.4
1.12 72.2-81.0-0.2
1.14 70.6-81.0-0.1
1.16 69.0-81.0-4.2-02
1.18 67.3-81.0-3.0-02
1.20 65.7-81.0-2.6-02
1.22 64.1-81.0-2.5-02
1.24 62.5-81.0-2.5-02
1.26 60.9-81.0-2.4-02
1.28 59.2-81.0-2.4-02
1.30 57.6-81.0-2.4-02
1.32 56.0-81.0-2.4-02
1.34 54.4-81.0-2.4-02
1.36 52.8-81.0-2.4-02
1.38 51.1-81.0-2.4-02
1.40 49.5-81.0-2.4-02
1.42 47.9-81.0-2.4-02
1.44 46.3-81.0-2.4-02
1.46 44.7-81.0-2.4-02
1.48 43.0-81.0-2.4-02
1.50 41.4-81.0-2.4-02
1.52 39.8-81.0-2.4-02
1.54 38.2-81.0-2.4-02
1.56 36.6-81.0-2.4-02
1.58 34.9-81.0-2.4-02
1.60 33.3-81.0-2.4-02
1.62 31.7-81.0-2.4-02
1.64 30.1-81.0-2.4-02
1.66 28.5-81.0-2.4-02
1.68 26.9-81.0-2.4-02
1.70 25.2-81.0-2.4-02
1.72 23.6-81.0-2.4-02
1.74 22.0-81.0-2.4-02
1.76 20.4-81.0-2.4-02
1.78 18.8-81.0-2.4-02
1.80 17.1-81.0-2.4-02
1.82 15.5-81.0-2.4-02
1.84 13.9-81.0-2.4-02
1.86 12.3-81.0-2.4-02
1.88 10.7-81.0-2.4-02
1.90 9.0-81.0-2.4-02
1.92 7.4-81.0-2.4-02
1.94 5.8-81.0-2.4-02
1.96 4.2-81.0-2.4-02
1.98 2.6-81.0-2.4-02
2.00 0.9-81.0-2.4-02
END OF STROKE

```
01♦LBL "RAMMER"
FIX 4  .013  STO 11
3000  STO 13  300
STO 14  1.375  STO 15
2.5  STO 16  2  STO 17
1.75  STO 18  1.5
STO 19  1.88  STO 20
1.85  STO 21  .06
STO 22  .03  STO 23
.011  STO 24  .7854
STO 25  .7854  STO 26
18.25  STO 27  2  STO 28
4  STO 29  87  STO 30
.008  STO 31  .0308
STO 32  165  STO 57  386
STO 33  /  STO 12  33.75
STO 58  .1  STO 59

55♦LBL "MU"
RCL 31  RCL 32  *
RCL 33  /  STO 34

62♦LBL "A1"
RCL 15  X↑2  PI  *  4  /
STO 35

70♦LBL "A2"
RCL 16  X↑2  RCL 15  X↑2
-  PI  *  4  /  STO 36

81♦LBL "A3"
RCL 16  X↑2  PI  *  4  /
STO 37

89♦LBL "A4"
RCL 17  X↑2  RCL 18  X↑2
-  PI  *  4  /  STO 38

100♦LBL "A5"
RCL 17  X↑2  RCL 19  X↑2
-  PI  *  4  /  STO 39

111♦LBL "C1"
17  STO 53  18  STO 54
XEQ "CX"  STO 40

118♦LBL "C2"
20  STO 53  XEQ "CX"
STO 41

123♦LBL "C3"
17  STO 53  21  STO 54
XEQ "CX"  STO 42

130♦LBL "C4"
RCL 17  X↑2  RCL 19  X↑2
-  STO 56  RCL 17
RCL 19  /  LN  STO 55  *
RCL 17  X↑2  X↑2  RCL 19
X↑2  X↑2  -  RCL 55  *
RCL 56  X↑2  -  /  32  *
RCL 34  *  STO 43

161♦LBL "C5"
20  STO 53  XEQ "CX"
STO 44  GTO "B1"

167♦LBL "CX"
RCL IND 53  X↑2  2  *
RCL IND 53  RCL IND 54
/  LN  STO 55  *
RCL IND 53  X↑2
RCL IND 54  X↑2  -
STO 56  -  RCL IND 53
X↑2  X↑2  RCL IND 54
X↑2  X↑2  -  RCL 55  *
RCL 56  X↑2  -  /  16  *
RCL 34  *  RTN

203♦LBL "B1"
RCL 35  RCL 13  *
RCL 36  RCL 14  *  +
RCL 37  *  RCL 38  *
RCL 39  RCL 14  *
RCL 37  X↑2  *  -
RCL 58  COS  RCL 59  *
RCL 58  SIN  +  RCL 57
*  RCL 37  X↑2  *  -
RCL 12  RCL 37  X↑2  *
RCL 11  RCL 38  X↑2  *
+  /  STO 60  STO 64
STO 68

248♦LBL "B1+"
RCL 38  RCL 13  *
RCL 39  RCL 14  *  -
RCL 58  COS  RCL 59  *
RCL 58  SIN  +  RCL 57
*  -  RCL 12  /  STO 72

269♦LBL "B1-"
RCL 38  RCL 39  -
RCL 14  *  RCL 58  COS
RCL 59  *  CHS  RCL 58
SIN  +  RCL 57  100  -
*  -  RCL 12  100
ENTER↑  386  /  -  /
STO 76

296♦LBL "B2"
RCL 38  RCL 35  *  3
Y↑X  RCL 37  /  RCL 22
X↑2  /  RCL 38  3  Y↑X
RCL 37  X↑2  *  RCL 24
X↑2  /  +  RCL 38  3
Y↑X  RCL 37  X↑2  *
RCL 25  X↑2  /  +
RCL 39  3  Y↑X  RCL 37
X↑2  *  RCL 26  X↑2  /
+  RCL 12  RCL 37  X↑2
*  RCL 11  RCL 38  X↑2
*  +  /  115.5  X↑2  /
STO 61  STO 65  STO 69

353♦LBL "B2+"
RCL 38  3  Y↑X  RCL 25
X↑2  /  RCL 39  3  Y↑X
RCL 26  X↑2  /  +
STO 77  RCL 38  3  Y↑X
RCL 22  X↑2  /  +
RCL 12  /  115.5  X↑2  /
STO 73

381♦LBL "B2-"
RCL 77  RCL 39  3  Y↑X
RCL 23  X↑2  /  +
RCL 12  100  ENTER↑  386
/  -  /  115.5  X↑2  /
STO 77

401♦LBL "B3B4"
RCL 27  RCL 28  +
RCL 29  -  RCL 40  *
RCL 29  RCL 28  -
RCL 42  *  +  RCL 28
RCL 44  *  +  STO 62
RCL 27  RCL 40  *
RCL 28  RCL 29  -
RCL 41  *  +  RCL 29
RCL 44  *  -  STO 66
RCL 27  RCL 29  -
RCL 40  *  RCL 28
RCL 41  *  +  RCL 29
RCL 42  *  +  STO 70
STO 74  RCL 40  STO 63
STO 71  STO 75  RCL 41
RCL 42  +  RCL 44  -
STO 67  RCL 39  ST* 62
ST* 63  ST* 66  ST* 67
ST* 70  ST* 71  ST* 74
ST* 75  RCL 30  RCL 43
*  RCL 39  *  ST+ 62
ST+ 66  ST+ 70  ST+ 74
RCL 43  RCL 39  *
ST- 63  ST- 67  ST- 71
ST- 75  RCL 12  RCL 37
X↑2  *  RCL 11  RCL 38
X↑2  *  +  RCL 37  X↑2
/  ST/ 62  ST/ 63
ST/ 66  ST/ 67  ST/ 70
ST/ 71  RCL 12  ST/ 74
ST/ 75  RCL 74  STO 78
RCL 75  STO 79  65
ENTER↑  165  /  ST/ 78
ST/ 79  FS? 02
GTO "DIF"

517♦LBL "DATA"
"RAMMER DATA"  SF 12
PRA  CF 12  CLA  DATE
ADATE  "├ "  TIME  ATIME
AVIEW  ADV  "M1="
ARCL 11  AVIEW  "M2="
ARCL 12  AVIEW  "PA="
ARCL 13  AVIEW  "PR="
ARCL 14  AVIEW  "D1="
ARCL 15  AVIEW  "D2="
ARCL 16  AVIEW  "D3="
ARCL 17  AVIEW  "D4="
ARCL 18  AVIEW  "D5="
ARCL 19  AVIEW  "D6="
ARCL 20  AVIEW  "D7="
ARCL 21  AVIEW  "A01="
ARCL 22  AVIEW  "A02="
ARCL 23  AVIEW  "A03="
ARCL 24  AVIEW  "A04="
ARCL 25  AVIEW  "A05="
ARCL 26  AVIEW  "L1="
ARCL 27  AVIEW  "L2="
ARCL 28  AVIEW  "L3="
ARCL 29  AVIEW  "L4="
ARCL 30  AVIEW  "NU="
ARCL 31  AVIEW  "RHO="
ARCL 32  AVIEW  "G="
ARCL 33  AVIEW  "MU="
ARCL 34  AVIEW  "A1="
ARCL 35  AVIEW  "A2="
ARCL 36  AVIEW  "A3="
ARCL 37  AVIEW  "A4="
ARCL 38  AVIEW  "A5="
ARCL 39  AVIEW  "C1="
ARCL 40  AVIEW  "C2="
ARCL 41  AVIEW  "C3="
ARCL 42  AVIEW  "C4="
ARCL 43  AVIEW  "C5="
ARCL 44  AVIEW  "WT="
ARCL 57  AVIEW  "ANG="
ARCL 58  AVIEW  "FRC="
ARCL 59  AVIEW  60.079
PRREGX  ADV

644♦LBL "DIF"
" TIME  X  "
"├VEL  ACC"  AVIEW
"------------"
"├----------"  AVIEW
SF 21  "RAM"  ASTO 07
"X0=?"  PROMPT  STO 02
"Y0=?"  PROMPT  STO 03
"Y0.=?"  PROMPT  STO 04

663♦LBL "OUT"
XEQ IND 07  STO 05  CLA
FIX 2  RCL 02  ACX
FIX 1  RCL 03  ACX
RCL 04  ACX  RCL 05  ACX
PRBUF  CLX
```

```
679*LBL 10
RCL 04  RCL 03  RCL 02
XEQ IND 07  XEQ 07
STO 05  STO 00  RCL 01
XEQ 06  STO 06  STO 00
RCL 01  RCL 00  RCL 04
+  RCL 05  XEQ 05
ST+ 06  ENTER↑  +
STO 00  RCL 01  ENTER↑
+  XEQ 06  RCL 06
ENTER↑  +  +  RCL 05  +
3  /  RCL 04  +  STO 04
LASTX  RCL 06  RCL 05  +
3  /  +  RCL 01  ENTER↑
+  STO 05  *  ST+ 03
RCL 05  ST+ 02  0
RCL 03  X<=Y?
GTO "DONE"  GTO "OUT"

736*LBL "DONE"
"END OF STROKE"  AVIEW
ADV  ADV  ADV  ADV  ADV
CF 00  CF 01  FIX 4
STOP

748*LBL 04
RCL 03  +  RCL 02
RCL 01  +  XEQ IND 07
XEQ 07  RTN

757*LBL 06
RCL 00  RCL 04  +
RCL 00

762*LBL 05
2  /  RCL 04  +  R↑  *
RCL 03  +  RCL 02  R↑  +
XEQ IND 07

775*LBL 07
RCL 01  *  RTN

779*LBL "RAM"
FS? 00  GTO "AA"  .005
STO 01  .01  FS?C 01
STO 01  RCL 03  2  -
SIGN  RCL 03  4  -  SIGN
+  RCL 03  57  -  SIGN
+  RCL 03  87  -  SIGN
+  4  +  2  *  60  +
STO 08  1  +  STO 09  1
+  STO 10  1  +  STO 11
79  X=Y?  SF 00  9  -
X=Y?  SF 01  FC? 00
GTO "AA"  "RETRACT RAM"
SF 12  PRA  CF 12  0
STO 02  87  STO 03  0
STO 04  .01  STO 01
GTO "OUT"

844*LBL "AA"
RCL IND 08  RCL IND 09
RCL 04  X↑2  *  FS? 00
CHS  -  RCL IND 10
RCL IND 11  RCL 03  *  +
RCL 04  *  -  STO 52
RTN  .END.
```

LTHD Ramner Hydraulic Circuit

The ramner circuit is shown in the attached illustration and consists of a flow control valve, a de-intensifier, variable orifice for controlling actuator speeds, a ramming actuator, a three position four way control valve providing a selection of ram or creep speeds, and a pilot actuated / mechanical reset two position control valve for reversing the actuator direction.

Operation of the hydraulic ramming circuit is as follows:

1. When the primary control valve is set to the ram position, a pilot signal is sent to the secondary control valve which shifts the two position spool to start the ramming action.

2. Main supply pressure is directed to the back of the flow control valve which sets the piston and spring assembly to open the valve and provide the desired flow characteristic to the rest of the circuit. At the same time, the pilot operated check valve at the inlet to the de-intensifier is closed.

3. Flow from the main flow control valve is directed through a variable, speed controlling orifice to the small piston of the de-intensifier.

4. This is a two speed rammer, and the purpose of the de-intensifier is to provide a large measured volume of low pressure fluid to the ramming actuator during the initial slow speed travel of the projectile tray through the transition tracks from the horizontal loading position to the barrel elevation angle, while making the most efficient use of the high pressure supply from the accumulator.

5. Flow from the large piston of the de-intensifier is directed to the ramming actuator through a variable, speed controlling orifice. This orifice is adjusted to provide a full flow actuator speed of thirty inches/second. This actuator speed is maintained throughout the first fifty-seven inches of actuator travel.

6. When the actuator travel reaches fifty-seven inches, the de-intensifier piston opens porting which allows a direct flow path from the main flow control valve to the actuator. The variable orifice at the outlet of the flow control valve is adjusted to provide a maximum ramming velocity of three hundred inches/second.

7. When the actuator reaches the end of the running stroke, a mechanical contact shifts the two position control valve to the return position. This removes pressure from the back of the main flow control valve, thus shutting off any flow from the main accumulator. At the same time, the two pilot operated check valves at either end of the de-intensifier are opened.

8. At this point, both ends of the running actuator are open to reservoir pressure. Due to the differential area of the piston in the actuator, the rod will extend, moving the projectile tray back to the load position.

9. Flow from the actuator is directed back to the reservoir through a variable, speed controlling orifice. This orifice is adjusted to provide a full flow actuator speed of sixty inches / second. This actuator speed is maintained throughout the full return stroke of actuator travel.

RAMMER EQUATIONS

$$M_1 \ddot{x}_1 = A_1 P_1 + A_2 P_2 - A_3 P_3$$

$$M_2 \ddot{x}_2 = A_4 P_4 - A_5 P_5 - W(\sin\theta + f\cos\theta)$$

$$x_1 = \frac{A_4 x_2}{A_3}$$

$$\dot{x}_1 = \frac{A_4 \dot{x}_2}{A_3}$$

$$\ddot{x}_1 = \frac{A_4 \ddot{x}_2}{A_3}$$

$$P_1 = P_A - \left(\frac{A_1 \dot{x}_1}{115.5 A_{01}}\right)^2 = P_0 - \left(\frac{A_1 A_4 \dot{x}_2}{115.5 A_3 A_{01}}\right)^2$$

$$P_2 = P_R$$

$$P_3 = \frac{A_1 P_1 + A_2 P_2 - M_1 \ddot{x}_1}{A_3} = \frac{A_1 P_1 + A_2 P_2}{A_3} - \frac{M_1 A_4 \ddot{x}_2}{A_3^2}$$

$$P_4 = P_3 - \left(\frac{A_4 \dot{x}_2}{115.5 A_{03}}\right)^2 - \left(\frac{A_4 \dot{x}_2}{115.5 A_{04}}\right)^2 - K_1 \dot{x}_2$$

$$P_5 = P_R + \left(\frac{A_5 \dot{x}_2}{115.5 A_{05}}\right)^2 + K_2 \dot{x}_2$$

$$A_1 = D_1^2 \pi (.25)$$

$$A_2 = (D_2^2 - D_1^2)\pi (.25)$$

$$A_3 = D_2^2 \pi (.25)$$

$$A_4 = (D_3^2 - D_4^2)\pi (.25)$$

$$A_5 = (D_3^2 - D_5^2)\pi (.25)$$

$$C_1 = 16\mu \left[\frac{2D_3^2 \ln\left(\frac{D_3}{D_4}\right) - (D_3^2 - D_4^2)}{(D_3^4 - D_4^4)\ln\left(\frac{D_3}{D_4}\right) - (D_3^2 - D_4^2)^2} \right]$$

$$C_2 = 16\mu \left[\frac{2D_6^2 \ln\left(\frac{D_6}{D_4}\right) - (D_6^2 - D_4^2)}{(D_6^4 - D_4^4)\ln\left(\frac{D_6}{D_4}\right) - (D_6^2 - D_4^2)^2} \right]$$

$$C_3 = 16\mu \left[\frac{2D_3^2 \ln\left(\frac{D_3}{D_7}\right) - (D_3^2 - D_7^2)}{(D_3^4 - D_7^4)\ln\left(\frac{D_3}{D_7}\right) - (D_3^2 - D_7^2)^2} \right]$$

$$C_4 = 32\mu \left[\frac{(D_3^2 - D_5^2)\ln\left(\frac{D_3}{D_5}\right)}{(D_3^4 - D_5^4)\ln\left(\frac{D_3}{D_5}\right) - (D_3^2 - D_5^2)^2} \right]$$

$$C_5 = 16\mu \left[\frac{2D_6^2 \ln\left(\frac{D_6}{D_7}\right) - (D_6^2 - D_7^2)}{(D_6^4 - D_7^4)\ln\left(\frac{D_6}{D_7}\right) - (D_6^2 - D_7^2)^2} \right]$$

$$\mu = \frac{\nu\rho}{g}$$

for $x = 0$ to $(l_3 - l_2)$

$$K_1 = C_1(l_1 + l_2 - l_3 + x) + C_2(0) + C_3(l_3 - l_2) + C_5(l_2)$$

let $R_1 = C_1(l_1 + l_2 - l_3) + C_3(l_3 - l_2) + C_5(l_2)$
$R_2 = C_1$

$$K_1 = R_1 + R_2 x$$

for $x = (l_3 - l_2)$ to l_3

$$K_1 = C_1(l_1) + C_2(l_2 - l_3 + x) + C_3(x) + C_5(l_3 - x)$$

let $R_1 = C_1(l_1) + C_2(l_2 - l_3) + C_5(l_3)$

let $R_2 = C_2 + C_3 - C_5$

$$K_1 = R_1 + R_2 x$$

for $x = l_3$ to l_4

$$K_1 = C_1(l_1 - l_3 + x) + C_2(l_2) + C_3(l_3) + C_5(0)$$

let $R_1 = C_1(l_1 - l_3) + C_2(l_2) + C_3(l_3)$
$R_2 = C_1$

$$K_1 = R_1 + R_2 x$$

for $x = 0$ to l_4

$$K_2 = C_4(l_4 - x)$$

let $R_3 = C_4(l_4)$

$$K_2 = R_3 - C_4 x$$

$$M_2 \ddot{x}_2 = A_4 P_4 - A_5 P_5 - W(\sin\theta + f\cos\theta)$$

$$M_2 \ddot{x}_2 = A_4\left[\frac{A_1 P_1 + A_2 P_2}{A_3} - \left(\frac{A_4 \dot{x}_2}{115.5 A_{03}}\right)^2 - \left(\frac{A_4 \dot{x}_2}{115.5 A_{04}}\right)^2 - K_1 \dot{x}_2\right]$$

$$- \frac{A_4^2 M_1 \ddot{x}_2}{A_3^2} - A_5 P_5 - W(\sin\theta + f\cos\theta)$$

$$\ddot{x}_2 = \frac{A_4\left[\frac{A_1 P_1 + A_2 P_2}{A_3} - \left(\frac{A_4 \dot{x}_2}{115.5 A_{03}}\right)^2 - \left(\frac{A_4 \dot{x}_2}{115.5 A_{04}}\right)^2 - K_1 \dot{x}_2\right] - A_5 P_5 - W(\sin\theta + f\cos\theta)}{M_2 + \frac{A_4^2 M_1}{A_3^2}}$$

$$\frac{A_4 A_1 P_1}{A_3} = \frac{A_4 A_1 P_A}{A_3} - \frac{A_4^3 A_1^3 \dot{x}_2^2}{(115.5)^2 A_3^3 A_{01}^2}$$

$$\frac{A_4 A_2 P_2}{A_3} = \frac{A_4 A_2 P_R}{A_3}$$

$$A_5 P_5 = A_5 P_R + \frac{A_5^3 \dot{x}_2^2}{(115.5)^2 A_{05}^2} + A_5 K_2 \dot{x}_2$$

$$A_4 K_1 \dot{x}_2 = (A_4 R_1 + A_4 R_2 x)\dot{x}_2$$

$$A_5 K_2 \dot{x}_2 = (A_5 R_3 - A_5 C_4 x)\dot{x}_2$$

$$\text{let } B_1 = \frac{\frac{A_4 A_1 P_A}{A_3} + \frac{A_4 A_2 P_R}{A_3} - A_5 P_R - W(\sin\theta + f\cos\theta)}{M_2 + \frac{A_4^2}{A_3^2} M_1}$$

$$\text{let } B_2 = \frac{\frac{A_4^3}{A_{03}^2} + \frac{A_4^3}{A_{04}^2} + \frac{A_4^3 A_1^3}{A_3^3 A_{01}^2} + \frac{A_5^3}{A_{05}^2}}{(115.5)^2\left(M_2 + \frac{A_4^2}{A_3^2} M_1\right)}$$

$$\text{let } B_3 = \frac{A_4 R_1 + A_5 R_3}{M_2 + \frac{A_4^2}{A_3^2} M_1}$$

$$\text{let } B_4 = \frac{A_4 R_2 - A_5 C_4}{M_2 + \frac{A_4^2}{A_3^2} M_1}$$

$$\ddot{x}_2 = B_1 - B_2 \dot{x}_2^2 - (B_3 + B_4 x_2)\dot{x}_2$$

Above equations hold for $x = 0$ to 57 inches

For 57 in. to 87 in. let $A_3 = A_1$
$A_2 = 0$
$M_1 = 0$
$A_{03} = \infty$

For retract 87 in to 0 in let $A_3 = A_2$
$A_{01} = \infty$
$A_{03} = A_{02}$
$P_A = 0$
$M_1 = 0$
$W = W - 100\#$
$M_2 = M_2 - 100/386$

```
WWWWWWWWWW    1111111111111111111111111111111111111111111111111111    WWWWWWWWWW
WWWWWWWWWW    Digital Equipment Corporation - VAX/VMS Version V4.4     WWWWWWWWWW
WWWWWWWWWW    1111111111111111111111111111111111111111111111111111    WWWWWWWWWW

     M    M    222     000    EEEEE    222     000
     MM  MM   2   2   0   0   E       2   2   0   0
     M M M       2   0  00   E           2   0  00
     M    M     2    0 0 0   EEEE       2    0 0 0
     M    M    2     00  0   E          2     00  0
     M    M   2      0   0   E         2      0   0
     M    M  22222    000    EEEEE   22222    000


        RRRRRRRR       AAAAAA     MM       MM
        RRRRRRRR       AAAAAA     MM       MM
        RR      RR    AA    AA    MMMM   MMMM
        RR      RR    AA    AA    MMMM   MMMM
        RR      RR    AA    AA    MM  MM  MM
        RR      RR    AA    AA    MM  MM  MM
        RRRRRRRR      AA    AA    MM       MM
        RRRRRRRR      AA    AA    MM       MM
        RR   RR       AAAAAAAAAA  MM       MM
        RR   RR       AAAAAAAAAA  MM       MM
        RR    RR      AA    AA    MM       MM
        RR    RR      AA    AA    MM       MM
        RR      RR    AA    AA    MM       MM
        RR      RR    AA    AA    MM       MM


                FFFFFFFFFF     OOOOOO     RRRRRRRR        ;;;;        11
                FFFFFFFFFF     OOOOOO     RRRRRRRR        ;;;;        11
                FF            OO    OO    RR      RR      ;;;;      1111
                FF            OO    OO    RR      RR      ;;;;      1111
                FF            OO    OO    RR      RR                  11
                FF            OO    OO    RR      RR                  11
                FFFFFFFF      OO    OO    RRRRRRRR        ;;;;        11
                FFFFFFFF      OO    OO    RRRRRRRR        ;;;;        11
                FF            OO    OO    RR  RR          ;;;;        11
                FF            OO    OO    RR  RR          ;;;;        11
          ....  FF            OO    OO    RR    RR          ;;        11
          ....  FF            OO    OO    RR    RR          ;;        11
          ....  FF              OOOOOO    RR      RR        ;;      111111
          ....  FF              OOOOOO    RR      RR        ;;      111111
```

File _HSC000$DUA9:[M20.IRELAND_JV.VMS]RAM.FOR;1 (1699,21,1), last revised on 16-MAR-1987 09:52, is a 4 block sequential file owned by UIC [M20,IRELAND_JV]. The records are variable length with implied (CR) carriage control. The longest record is 61 bytes.

Job AODAT (375) queued to LN on 24-APR-1987 11:31 by user M20E20, UIC [M20,IRELAND_JV], under account M22 at priority 100, started on printer _VENUS$TXA6: on 24-APR-1987 11:36 from queue TXA6.

```
WWWWWWWWWW    1111111111111111111111111111111111111111111111111111    WWWWWWWWWW
WWWWWWWWWW    Digital Equipment Corporation - VAX/VMS Version V4.4     WWWWWWWWWW
WWWWWWWWWW    1111111111111111111111111111111111111111111111111111    WWWWWWWWWW
```

```
      DP=2.0
      DR=1.75
      DTR=0.
      DOV=1.0
      DOP=1.5
      DOTR1=.15
      DOTR2=.75
      G=386.087
      PA=775.
      PR=300.
      RHO=.0308
      VISCOS=.8
      W=150.
      THETA=45.
      CF=.3
      PI=3.14159
      AOV=PI*DOV*DOV/4.
      AOP=PI*DOP*DOP/4.
      AOTR1=PI*DOTR1*DOTR1/4.
      AOTR2=PI*DOTR2*DOTR2/4.
      RP=DP/2.
      RR=DR/2.
      AP=PI*RP*RP
      AR=PI*RR*RR
      ATR=PI*DTR*DTR/4.
      APR=AP-AR
      AP=1.374
      E1=(APR/(115.5*AOV))**2.
      E4=(AP/(115.5*AOP))**2.
      E5=(ATR/(115.5*AOTR1))**2.
      E6=(ATR/(115.5*AOTR2))**2.
      S=E5
      F1=LOG(RP/RR)
      F2=RP*RP
      F3=RR*RR
      F4=F2-F3
      F5=F2+F3
      E2=4.*RHO*VISCOS*(2.*F2*F1-F4)/((F5*F1-F4)*F4*G)
      ANGLE=THETA*PI/180.
      E3=PA*APR-PR*AP-W*(SIN(ANGLE)+CF*COS(ANGLE))
      XRAM=0.
      XDRAM=0.
      T=0.
      COUNT=4.
      DT=.005
  100 C1=-1.
      C2=1.
      C3=-1.
      DXRAM=0.
      DXDRAM=0.
      XRAMK=0.
      XDRAML=0.
      DO 200 I=1,4
      C1=C1+2.*C2
      C2=C2-.5
      D1=1.5-C1*.5+C3
      C3=0.
      XEFF=XRAM+D1*XRAMK
      XDEFF=XDRAM+D1*XDRAML
      XRAMK=DT*XDEFF
      R=E3-((3.*E1*APR+E4*AP+E5*ATR)*XDEFF+E2*APR*XEFF)*XDEFF
      XDRAML=DT*(G/W)*R
```

```
      DXRAM=DXRAM+C1*XRAMK
      DXDRAM=DXDRAM+C1*XDRAML
  200 CONTINUE
      T=T+DT
      XRAM=XRAM+DXRAM/6.
      XDRAM=XDRAM+DXDRAM/6.
      IF(E5.GT.S) GO TO 250
      IF(COUNT.LT.4.) GO TO 350
  250 PRINT 300,T,XRAM,XDRAM
  300 FORMAT(3X,F6.4,4X,F7.3,4X,F7.3)
      COUNT=0.
  350 IF(XRAM.GT.57.) E5=E6
      IF(XRAM.GE.85.) GO TO 400
      IF(T.GE.2.5) GO TO 400
      COUNT=COUNT+1.
      GO TO 100
  400 STOP
      END
```

PART NUMBERS: 1258570-225, AIR/HYRAULIC SERVICE BRAKE SYSTEM ASSY
12585748, Rotor

DESCRIPTION: PARKING AND SERVICE BRAKES

See status section below for detailed description of system.

STATUS:

The LTHD air/hydraulic service brake system assembly and functional schematic can be found in TDP, Dwg. 12585710-225. FMC has worked with Hayes Industrial Brake to finalize all specifications for the service brake system. Drawings for all parts can be found in the TDP. The basic operating principles for the service brake system are identical to that of the M198. In addition, on-line filters were added to keep contaminants out of the emergency valve, since contaminants in the valve has been the cause of past M198 brake system malfunctions. Service brakes are used on all four wheels.

The LTHD also uses a parking brake on each front wheel. The two parking brakes must be set to hold the LTHD on sloping ground during the displacement operation. The system consists of Tol-O-Matic brake calipers and a linkage and brake handle on the left and right hand front side. The completed drawings for this design can be found in the TDP.

The rotor (TDP, Dwg. 12585748) for each wheel consists of machined 6061 25v/o Al/SiCp extrusion (TDP, Dwg. 12586016-003).

Calculations of the load holding requirements for each of the brakes can be found in the following pages of this section.

AUTHOR: Dave Boudreau

10-27-86 24
JR Rondeau

LTND

TORQUE PER WHEEL FOR REQD BRAKING

REF. LAND CRAFT BOOKLET

$$T = \frac{W_G R \times 12}{g N} = \frac{(9000)(16.3)\left(\frac{14}{12}\right)(12)}{(32.2)(4)} = 15{,}946 \text{ POUND IN PER WHEEL}$$

T = TORQUE PER WHEEL IN POUND INCH — 63,782 PER 4 WHEELS

W = WEIGHT OF VEHICLE IN POUNDS

g = DECEL IN FT/SEC²

R = EFFECTIVE ROLL RADIUS IN FT

N = NO. OF WHEELS

g = 32.2

$$g = \frac{1.467 V}{T_S} \text{ OR } \frac{1.076 V^2}{D_S} \qquad \frac{1.076 (55)^2}{200} = 16.$$

g = DECEL IN FT/SEC²

V = VELOCITY IN MPH

T_S = STOPPING TIME IN SEC

D_S = DIST IN FT.

HAYES SERIES 41-25 DEMAND AT 2000 POUND PER PAD CAPACITY SET @ 1500 PSI @ 8 [illegible]

BASED ON REQMTS OF MIL HDBK-405

LTHD BRAKE STOPPING T 6W12

$$a = \frac{1.076\,V^2}{S} = \frac{1.076\,(20)^2}{30} = 14.34\ \text{FT/SEC}^2$$

$$T = \frac{W a R \times 12}{g\,N} = \frac{(9000)(14.34)(14)(12)}{(32.2)(4)} = 14{,}028$$

POUND INCHES / WHEEL

BASED ON 20 MPH STOP IN 30 FEET

PARK BRAKE REQ.

$$T = \frac{W \sin\theta \times R}{GR}$$

T = TORQUE IN # IN.
W = [illegible] ON INCLINED PL
θ = ANGLE OF INCLINE =
R = ROLL RADIUS IN INCHES =
GR = GEAR RATIO

$$T = \frac{(9000)(\sin 31^\circ)(14)}{1/1}$$

$$T = 64{,}894\ \text{POUND IN}$$

$$T = \frac{(9000)(\sin 11^\circ)(14)}{1/1} = 24{,}042\ \text{POUND IN.}$$

LTHD BRAKE STOPPING TORQUE

$$a = \frac{1.076\,V^2}{DS} = \frac{1.076(20)^2}{30} = 14.34\ \text{FT/SEC}^2$$

$$T = \frac{WaR \times 12}{\eta N} = \frac{(9000)(14.34)\left(\frac{14}{12}\right)(12)}{(32.2)(4)} = 14{,}028$$

POUND INCH

=12E HAYES 4125

$T = 2.9\,P(R - .76)$ $\mu = .70$

$= (2.9)(500)(7.5 - .75)$

$= 29{,}319$ POUND INCH

SERIES 41-2 HAS A HIGHER RATING

HAYES 41

$T = 4.14\,\mu P\left(\frac{D}{2} - .25\right)$

μ - ASSUME COEF. OF .35

$= (4.14)(.35)(500)\left(\frac{15}{2} - .25\right)$

$= 14{,}071$ POUND INCH

Selecting the Right Brake

Optimum performance for your application

To pick the brake and rotor combination that will provide the optimum performance for your particular application, three major factors must be considered — the braking torque required, which affects the choice of caliper unit; the maximum kinetic energy absorption required, which affects the choice of rotor; and the mechanical and environmental requirements, which affect the installation.

Torque...

Torque requirements are very often the primary consideration in selecting a design. Torque curves and torque ratings given for each caliper unit listed, indicate a torque that can safely be expected under normal operating conditions with the rotor and applied force specified. A simple torque formula is given for each brake, based on the effective rotor radius and the applied braking effort.

In selecting an appropriate brake unit the following equations are useful for estimating torque requirements:

For Stopping a Rotating Mass

$$T = \frac{0.00326\ I \times 12}{t}$$

where T = required torque in lbs. in.
I = inertia of mass in lbs. ft²
n = initial velocity of mass in rpm
t = time of stop in seconds

$$T = \frac{5252\ H \times 12}{n}$$

where T = required torque in lbs. in.
H = horsepower absorbed in hp
n = constant velocity in rpm

For Braking a Moving Vehicle

$$T = \frac{W\ a\ R \times 12}{gN}$$

where T = torque per wheel in lbs. in.
W = total vehicle weight in lbs.
a = rate of deceleration in ft./sec²
R = effective rolling radius in ft.
N = number of braked wheels
g = 32.2

← IN FT NOT INCHES SO (12) DROPS OUT

For Braking a Parked Vehicle

$$T = \frac{W\ SIN\ \theta \times R}{Gr}$$

where T = torque required in lbs. in.
W = total vehicle weight in lbs.
θ = angle in degrees
R = effective rolling radius in in.
Gr = gear ratio to braked shaft

For Determining Deceleration Rates

$$a = \frac{1.076\ V^2}{D_s}$$

$$a = \frac{1.467\ V}{t_s}$$

where a = deceleration in ft./sec²
V = velocity in miles per hour
t_s = stop time in seconds
D_s = distance to stop in ft.

Energy Absorption...

Any moving object possesses kinetic energy and arresting that motion necessarily generates heat that must be dissipated. Disc brakes, by the very nature of their design, offer superior energy absorbing characteristics. The rotor acts as an excellent 'heat sink.' Since at any given time it is receiving heat through only a small fraction of its surface area, the rest of the rotor is available to dissipate heat to the surrounding air. Just as torque affects caliper unit design, kinetic energy absorption affects rotor design. Under normal conditions disc brakes are relatively fade free and can be operated successfully at far higher temperatures than a comparable drum or band type brake.

The ability of a disc brake to absorb and dissipate heat (kinetic energy) depends on several factors:

1. The effective rubbed area of the rotor
2. The effective rotor mass
3. Ambient temperature and additional forced cooling
4. Rotor design and material
5. Permissible maximum operating temperature

The following equations are useful for estimating kinetic energy requirements:

For a Rotating Mass

$$KE = 0.00017\ I\ n^2$$

where KE = kinetic energy in ft. lbs.
I = inertia of mass in lbs. ft²
n = initial velocity in rpm

For Stopping a Moving Vehicle

$$KE = 0.0334\ WV^2$$

where KE = kinetic energy in ft. lbs.
W = total weight of vehicle in lbs.
V = initial velocity in mph

For Total Energy Input Over a Specified Period

$$KE = \frac{2\ n\ N\ T}{12}$$

where KE = kinetic energy in ft. lbs.
N = total number of rotor revolutions in that time
T = applied torque in lbs. in.
n = 3.1416

Mechanical and Environmental Considerations

Although the basic specification of the brake may well be determined by the first two considerations, the actual design and configuration finally selected is often dictated by the operating environment and space restrictions imposed by the equipment in question. The physical layout may determine whether simple mechanical actuation is feasible or the more flexible hydraulic or pneumatic actuation is to be preferred. It may also determine the choice of fixed or floating mount configurations.

Operating environment and duty cycle are frequently the major factors in brake selection. Some models will work well in dirty environments, others will not. The result of comprehensive life cycle testing on your machine in its expected duty cycle and operating environment is the final brake decision factor.

PART NUMBERS: 12585802, Primer Autoloader
12585710-240, Assembly
12585726, Primer Actuator

DESCRIPTION: PRIMER AUTOLOADER

See status section below for detailed description of system.

STATUS:

Primer Autoloader -

The FMC LTHD uses a modified FMC-developed primer autoloader (TDP, Dwgs. 12585802, 12585710-240 - assembly) in order to meet LTHD loading time cycle requirements. This autoloader was not funded under contract. The autoloader holds 20 primers in a replaceable drum and can be actuacted hydraulically (as in normal operation) or manually (in a degraded mode). An operational description of the autoloader can be found within the writeup of Misfire Procedure Tasks (TDP, Dwg. 12585710-825, shts 24-26) since primer inspection is required in these tasks.

A prototype FMC primer autoloader is currently being manufactured at this time, with a rigorous testing program to follow. The LTHD-required modifications to the autoloader include the addition of a hydraulic lanyard actuator as well as a ring to hook on a lanyard for use in degraded operation. The locations and specifications for tapped holes in the Benet Breech Housing have been approved by Benet.

Primer Actuator and Hoses -

Mounting and size requirements for the primer actuator (TDP, Dwg. 12585726) have been determined and were provided to York to be finalized. These requirements were developed to be compatible with both the FMC primer autoloader and also the Benet Breech Housing.

All hoses, fittings and connectors have been finalized and are specified on FMC TDP gang-sheets. Layouts of the primer actuator and hoses can be found in the TDP, Cannon Assembly.

AUTHORS: Tim Doering, Joe Turek, Jeff Ireland

LTHD ACTUATORS

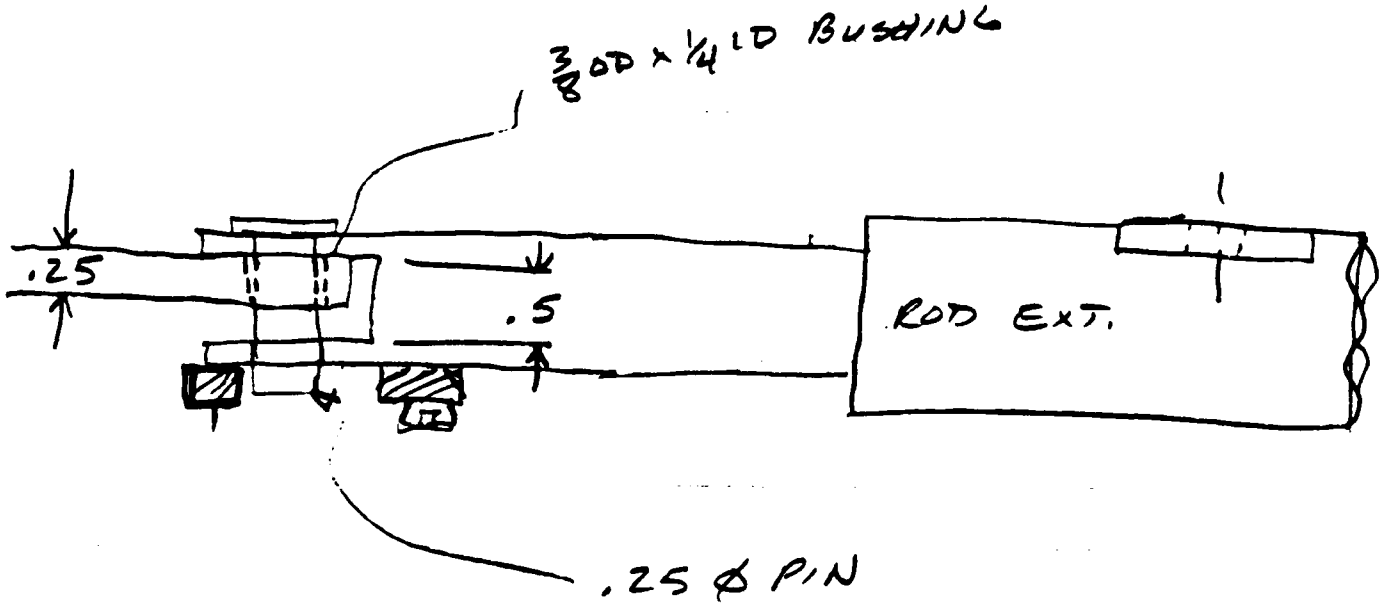
AUTO PRIMER ACTUATOR

PISTON DIA		in.
ROD DIA		in.
WORKING PRESSURE	3000	psi
PROOF PRESSURE	4500	psi
EXTEND FORCE	50	lbs.
EXTEND OIL FLOW		gpm
RETRACT FORCE	20	lbs.
RETRACT OIL FLOW		gpm
EXTENDED LENGTH	12.125	in.
RETRACTED LENGTH	7.625	in.
STROKE	4.5	in.
EXTEND CUSHION LENGTH		in.
RETRACT CUSHION LENGTH		in.
ACTUATOR ENDS:		
CYLINDER END	CYL BOLTED TO BAND	
ROD END	ROD END THREADED TO PRIMER INDEXING SLIDE.	
ACTUATOR WEIGHT	2.5	lbs.
SHOCK FACTOR	20	g's

COMMENTS:

A-2

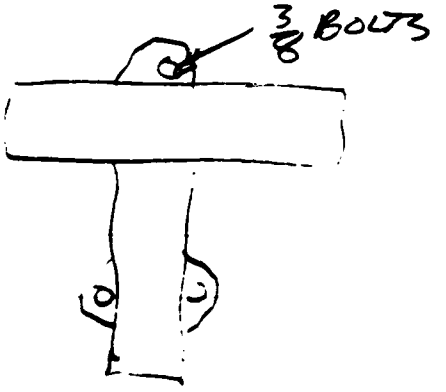
AUTO PRIMER



ALLOW .25 MAX FOR BRACKET MOVEMENT

.25 PIN A = .0491

$S = \frac{195.9}{.0491} = 3,989$



3/8 BOLT A = .1104

$S = \frac{195.9}{.1104} = 1,774$ 1 BOLT

3 BOLT = $\frac{1774}{3} = 591.48$

AUTO PRIMER P1
ACT.

.0883 X 3000 = 264.90
.6896 X 100 = 69.96
.0883 X 300 = 26.49
.6896 X 300 = 206.88
.0883 X 100 = 8.83

3000 264.90
100 - 68.96
195.94

3000 264.90
300 -206.88
58.02

100 68.96
100 8.83
60.13

300 206.88
300 26.49
183.39

5

$\frac{15}{16}$ = .883 100psi

$\frac{7}{8}$ = .6013

$\frac{15}{16} \times \frac{7}{8}$

264.90 3000
- 8.83 100psi
256.07

264.90 3000
26.49 300
238.41

206.88 300
- 26.49 300
180.39

68.96 100
- 8.83 100
60.13

PIN
.25 = $\frac{256.07}{.0491}$ = 5,216

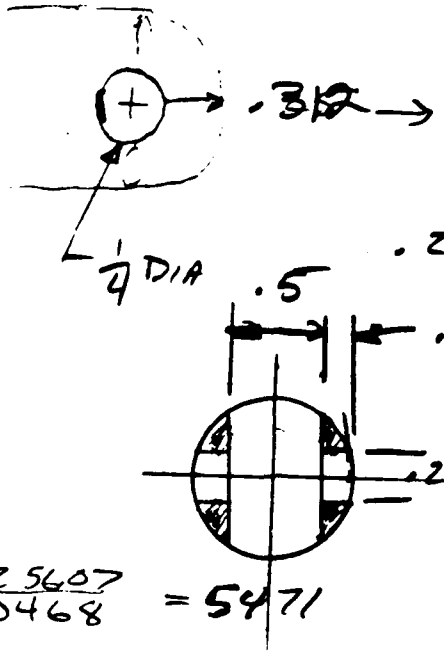
BUSHING 1/4 ID x .3/8 OD
A = .25 x .25 = .0625

$\frac{256.07}{.0625}$ = P = 4,097

DISOGRIN # 110-006 P43D

ROD WIPER .875 X 1.375 D X .362 LGTH.

ROD SEAL .875 X 1.125 X .281 001-05K P.9D



$\frac{256.07}{.0625}$ = P = 4097

.187 x .187 = .035

$\frac{256.07}{.0468}$ = 5471

$\frac{264.9}{.0350}$ = ~~7568~~ SEE A-1

P3 1/28/86

6

$\frac{60}{.4} = 150 \times 4.5$ STROKE $= 675$ "PER MIN

1" A = .785
7/8 A = .6013
15/16 A = .6896

.785 − .6013 = .1837

3/8" A = .1104

.1837 × 3000 psi = 551.03
.0954 × 3000 psi = 286.32
.0883 × 3000 = 264.90 X
15/16 − 7/8

.6896 551.03 *
− .6013 − 78.50
.0883 472.53

264.90 − 206.88 = 58.02

.6896 − .1104 = .5792

.785 × 300 psi = 235.5
.785 × 100 psi = 78.50
.0954 × 300 psi = 28.62
.0883 × 300 = 26.49 X
.0883 × 100 = 8.83 X
15/16 .6896 × 300 = 206.88 X
.6896 × 100 = 68.96 X
.5792 × 100 = 57.91
.5792 × 300 = 173.74
.6896 × 3000 = 2069 X STATIC

264.90 − 173.74 = 91.15

57.91 − 26.49 = 31.42

300 264.90 − 206.49 = 58.02

3000 264.90 − 68.96 = 195.94

300 206.88 − 26.49 = 180.39

100 68.96 − 8.96 = 60.00

3000 2,068.9 − 68.96 = 2000

3000 × .6896 = 2,068.8 #

2000 ÷ .0491 = 40,733 #

120,000 y (.577) = 69,240

1/4 PIN SEEN 3000 psi = 1.7 TO 1

P4

7

A 1⅛ = .994

A ⅜ = .6013

.3927 x .187 = .0734 — 1.178

3000 psi x .3927 = 1.178 = p = 16,050

4 50,000 (.577) = 28.850 ÷ 16,050 = 1.8 TO 1

$\frac{60}{.4} = 150 \times 4.5 = 675$ " PER MIN

$.6496 \times 675 = \frac{465.48}{231} = 2.015$ GPM

$\times 2$

4.03

26' PER SEC Ø.25 HOLE

$.0683 \times 675 = \frac{59.60}{231} = .254$

$\times 2$

.516

3' PER SEC Ø.25 HOLE

$$M\ddot{x}_{00}^{Ac} = -(A_P - A_R)\left[P_R + \left[\frac{(A_P - A_R)\dot{x}_0^U}{115.5\,A_{OP}}\right]^2\right] + \left[P_R - \left(\frac{(A_P)\dot{x}}{115.5\,A_{OP}}\right)^2\right]^9 A$$

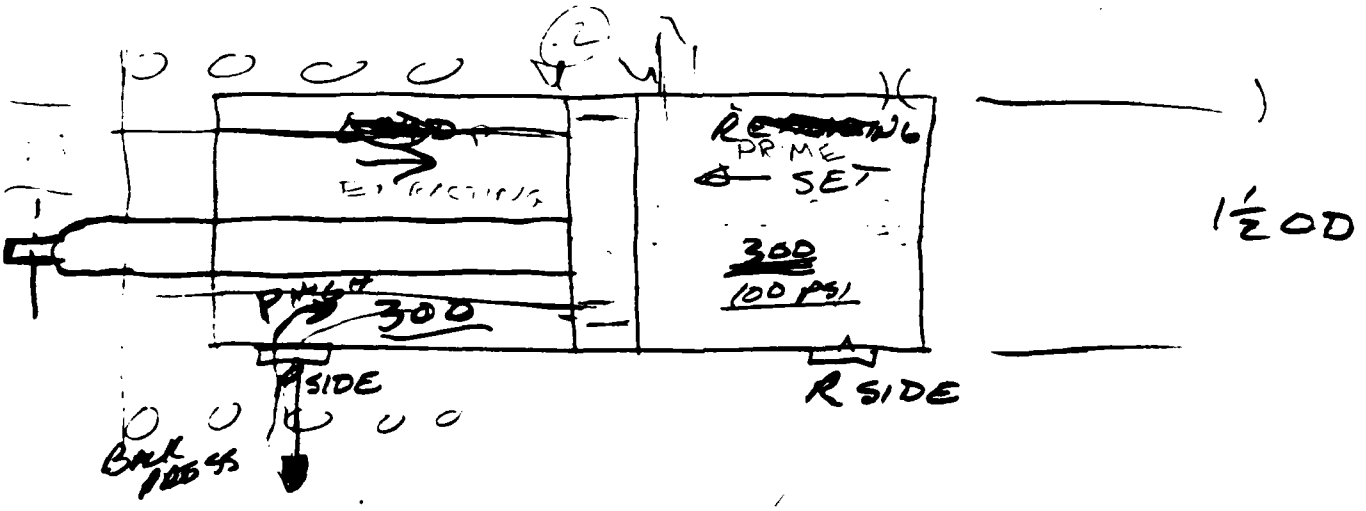
$F = P A$

$F = 50^{\#}$

$P = 3000$

RETURN 300

1.05



½ ROD $A = .1963$

$\frac{F\ 50}{P\ 3000} = A$

$A = .0167$

$\frac{50}{.0167}$

1" $A = .785$

3/4 $A = .4418$

GUESSION

$U = 4.5 \times .785 = 3.53$

$GPM = \frac{3.53}{231} = .0153$

3/4 .4418

1/2 .1963

.2455

.4418

$U = 4.5 \times .4418 = \frac{1.9881}{231} = .009$

$U = 4.5 \times .2455 = \frac{1.1048}{231} = .005$

A-1

$h = .187$
$c = .717$
$L = .8399$
$R = .4375$
$\alpha = 110°$
$c/R = 2.7486$

$A = \frac{1}{2}[.4375(.8399) - 717(.4375 - .187)]$
$.3675 - 717 \quad (.25)$
$.3675 - .1793 =$
$A = \frac{1}{2}[.1883]$
$A = .5(.1883)$
$A = .0941 \times 2 = .188$

$A = .188 - .093 = .094$

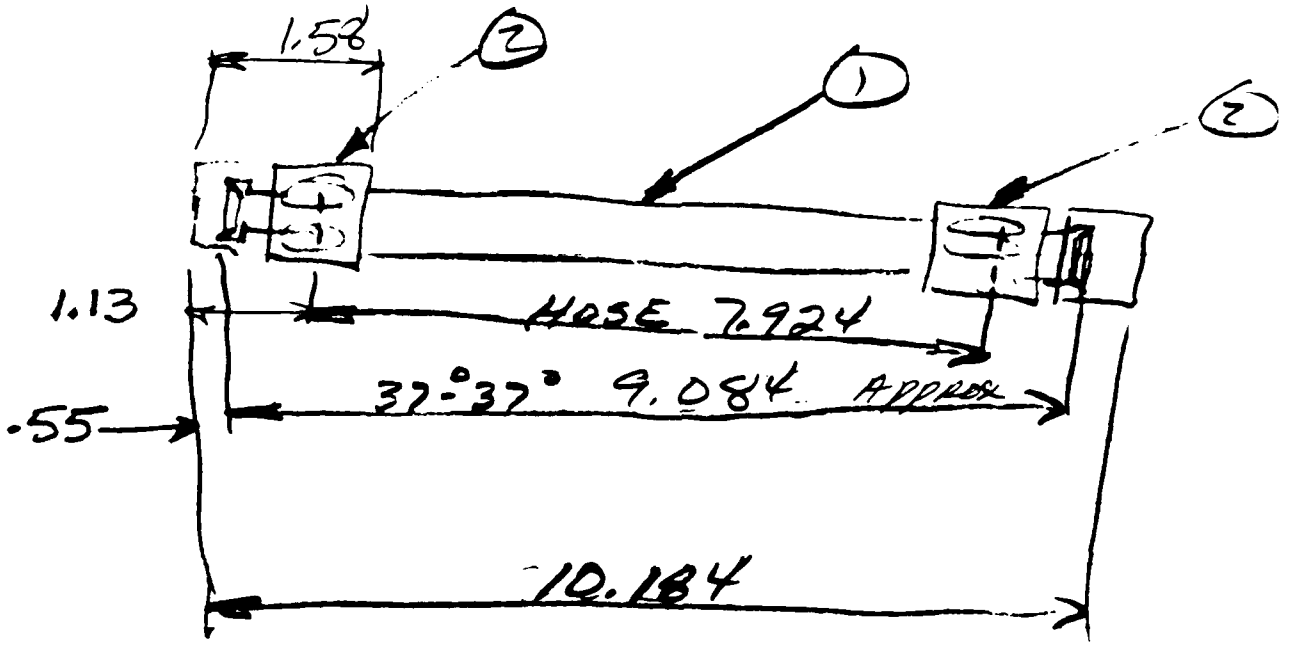
$\frac{196}{.094} S = 2085$

$\frac{2000}{.094}$ BENDING ?
$= 21,276$

T-12586037/A (004)

3/7/87

HOSE FOR PRIMER TO BAND



ITEM 1 HOSE QTY 1 AERO 2807-4 X 9.56 LG

FITTING 63-190600-4 S.STL 37°F BOTH ENDS

87/3/7

(A)

5" R = C 31.4159/360 x 15° = 1.309

6.75 + 2.125 + 1.309 = 10.184

(B)

5.875 = 369137/360 x 15 = 1.538

6.5 + 2.125 + 1.538 = 10.16

15°

(C)

8.5 = 53.4071/360 x 10 = 1.483

10°

6 + 2.625 + 1.483 = 10.108

END

10-87

DTIC